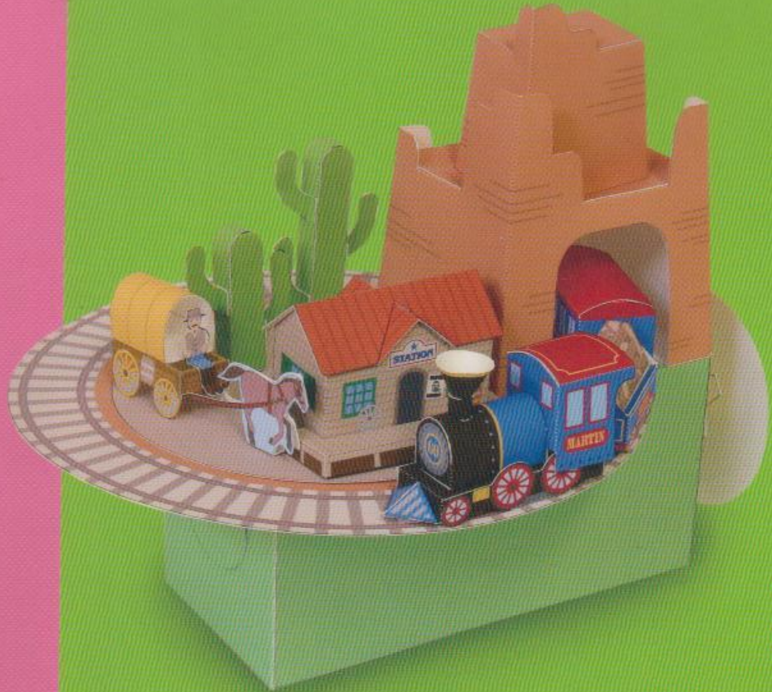
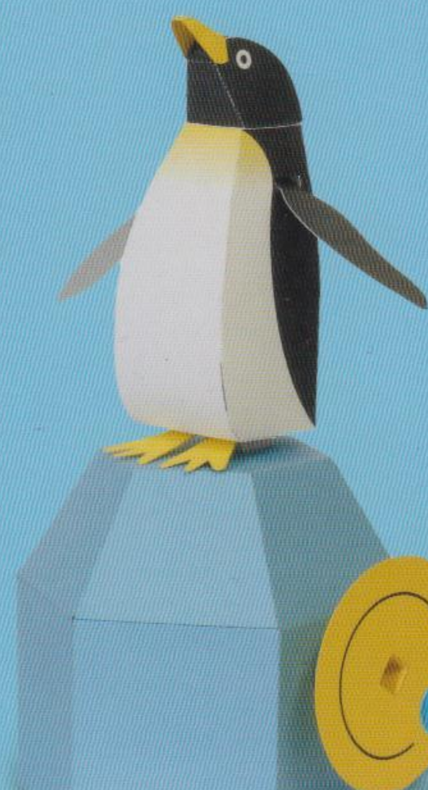


# KARAKURI

## HOW TO MAKE MECHANICAL PAPER MODELS THAT MOVE



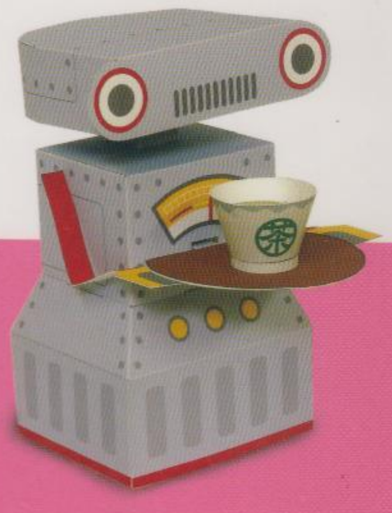
Keisuke Saka

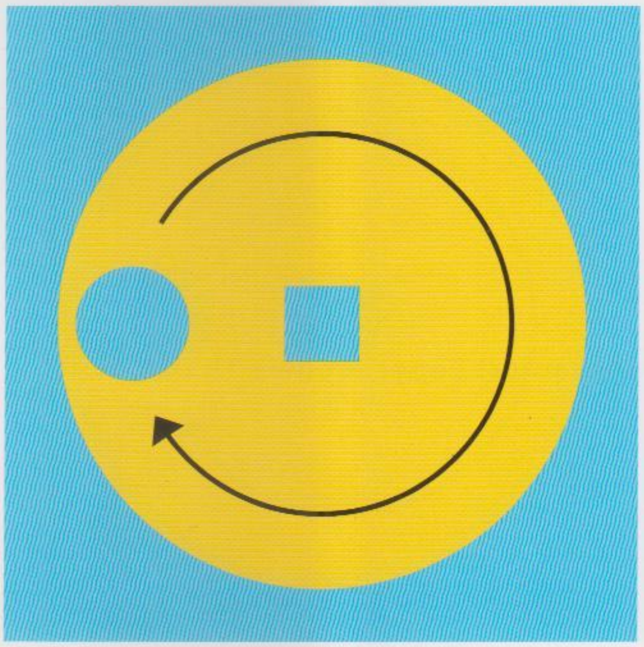
ISBN 978-0-312-56669-2 $24.99/$29.99 Can.

Originally published in Japan, *Karakuri* is an introduction to the simple mechanisms, such as gears, cranks, cams, and levers, used to bring to life these amazing moving paper models or automata. Included are pull-out pages for you to use to construct your own moving models of the different types of gears. These models serve as the basis for designing your own karakuri or may just be admired on their own.

Detailed explanations, accompanied by diagrams, explain the physics behind how karakuri move and operate, so you really learn about the properties of the different types of gears and cams. And to inspire you, also included are four fun, full-color karakuri models designed by the author, a well-known paper engineer. Printed on pull-out pages and easily assembled, the projects include a whimsical tea-serving robot, an amusing penguin perched on an iceberg and trying to fly, a delightful peek-a-boo-playing teddy bear, and a mesmerizing train that goes around on a track and through a tunnel!

With complete directions, fourteen full-size models, and the science behind the craft revealed, this book is a unique introduction to an ancient art.





**Karakuri - How to Make Mechanical Paper Models That Move**
**Keisuke Saka**

| | |
|---|---|
| **Paper-craft and text** | Keisuke Saka |
| **Advisors** | Masayuki Kobayashi |
| | Yasuyuki Shirai |
| | Toshio Arai |
| **Design** | Keisuke Saka, Kohei Masukawa, Eri Hamaji (Redesign/Production) |
| **Translation** | Eri Hamaji |
| **Special Thanks** | Students at Tama University Hijirigaoka High School, Tokyo, Japan |

This book is translated and redesigned from the original book published in Japan:
Keisuke Saka. *Karakuri no Moto: Paper Craft Book*. Tokyo, Japan: Shubunsha, 2007.

Permission to reproduce the Ready to Fly (Climate Change) model granted by Doug Wolske/Noted, LLC.



www.stmartins.com

Library of Congress Cataloging-in-Publication Data

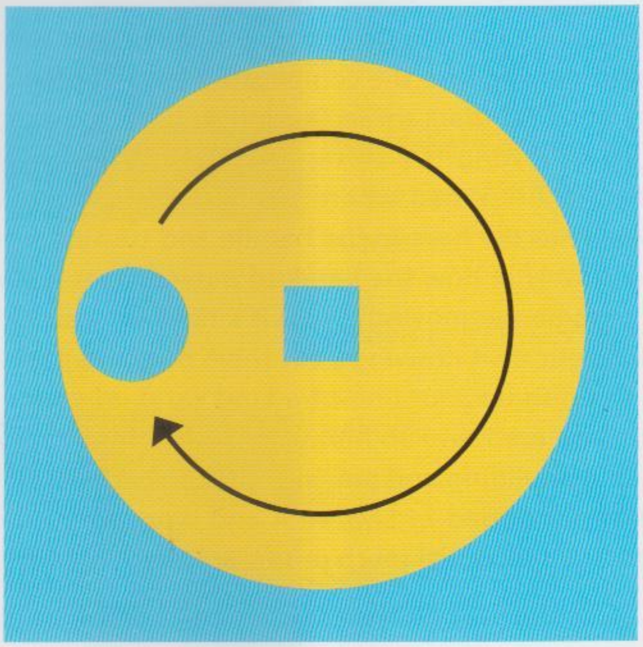
ISBN-13 978-0-312-56669-2

First Edition: March 2010

10 9 8 7 6 5 4 3 2 1

# karakuri

## HOW TO MAKE MECHANICAL PAPER MODELS THAT MOVE




**Keisuke Saka**

**Translated by Eri Hamaji**



St. Martins Griffin
New York

# How to Use This Book

## Make an original karakuri

In Section 1, Karakuri Gallery, you can see some sample karakuri paper crafts made by Keisuke Saka as well as others made by Japanese high school students as a summer project based on the various karakuri diagrams found in this book. Can you imagine how each of them actually moves?

For those of you who want to go ahead and make your own karakuri paper craft without delving into the complicated laws of physics, you can start cutting out a model diagram in Section 4, Basic Karakuri Models, and building it by following the corresponding instructions in Section 3, How to Build Karakuri. When you're done building, try the karakuri by sticking a finger into the hole in the handle and turning it round and round. Then look closely at how the karakuri moves. Does it start to look like something or someone moving? Now it's time for you to get more creative and make your own drawings, cut them out, and paste the parts onto the model to finish up your one-of-a-kind karakuri paper craft!

In Section 5, there are four Fun Karakuri Models designed by Keisuke Saka for you to enjoy building and playing with. They are applications of the simple machines included in Section 4 and work in combination of two or more. Can you tell which mechanisms are used in each toy?

## Learn how things work

In Section 2, How Karakuri Work, you will be introduced to the basic logic behind some important karakuri mechanisms. Easy-to-see diagrams help you understand the way they work, and you will also learn that karakuri mechanisms are found in common tools and machines we may use every day without even knowing. The paper-craft models in this book bring the laws of physics behind such items into the 3-D realm.

Those who find the descriptions of karakuri mechanisms in Section 2 to be too wordy and difficult to understand may benefit from first building the models and actually seeing the theories come to life at the turn of a finger. Rereading the explanations after building the model will probably give you a better understanding of how karakuri work.

# The 10 Basic Karakuri Models to Assemble

## Cam A*

The rod makes a repetitious vertical motion.

INSTRUCTION ▶ p.36
MODEL ▶ p.65

## Cam B*

Two rods make a vertical movement alternately.

INSTRUCTION ▶ p.37
MODEL ▶ p.69

## Cam C*

The rod makes a repetitious horizontal movement.

INSTRUCTION ▶ p.38
MODEL ▶ p.73

## Cam D*

The rod slides repeatedly in a linear motion.

INSTRUCTION ▶ p.39
MODEL ▶ p.77

## Crank A

The rod sways repeatedly in a circular motion.

INSTRUCTION ▶ p.40
MODEL ▶ p.81

## Crank B

The rod sways back and forth by a linkage mechanism.

INSTRUCTION ▶ p.41
MODEL ▶ p.85

## Crank C

The turning of the crank is converted into a vertical motion.

INSTRUCTION ▶ p.42
MODEL ▶ p.89

## Gear A*

The gear turns horizontally to the handle.

INSTRUCTION ▶ p.43
MODEL ▶ p.93

## Gear B*

Thegearturnsperpendicularly to the handle.

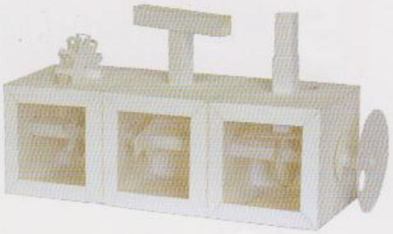
INSTRUCTION ▶ p.44
MODEL ▶ p.97

## Geneva Stop*

A wheel makes turns in a discontinuous rhythm.

INSTRUCTION ▶ p.45
MODEL ▶ p.101

* These seven karakuri models can be combined to make a model connected with one handle, using the parts on page 105.

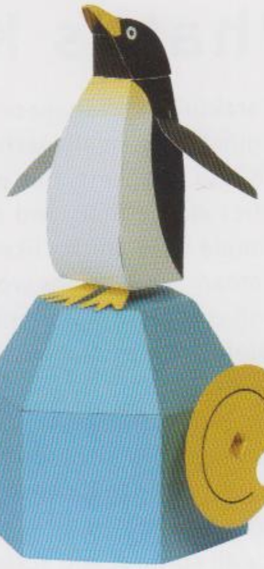


# The 4 Fun Karakuri Models to Assemble

## Tea-Serving Robot

The traditional Japanese tea-serving doll makes a futuristic comeback. Roll the robot forward to serve the tea—be careful; he's a clumsy little thing!

INSTRUCTION ▶ p.46 MODEL ▶ p.113



## Ready to Fly

A penguin is standing on a glacier and frantically flapping its wings, hoping to fly away. As the body of the penguin moves, the wings sway up and down.

INSTRUCTION ▶ p.48 MODEL ▶ p.117

## Peek-a-Bear

This friendly-looking bear is actually quite a shy guy. Moving on a crank, he covers his face with his paws but takes a sneak peek at you every few seconds.

INSTRUCTION ▶ p.50 MODEL ▶ p.125

## Wild Wild West

The tunnel is attached to the base and to the slightly elevated disk at the center. The railroad train moves round while the tunnel and the scenery stand still.

INSTRUCTION ▶ p.52 MODEL ▶ p.133

# What Is KARAKURI?

"Karakuri" is a Japanese word that means "mechanism." It originally meant all machineries introduced to Japan from China and the West, but in modern times the word often signifies classic dolls and retro toys that move amusingly via simple mechanisms like cams and gears. "Karakuri" can also mean "how things work," or the mysterious workings behind certain things. For example, there are Japanese expressions such as "karakuri of a magic trick" or "karakuri of an incident."

In the middle of the 16th century, the arrival of Portuguese ships introduced the Japanese to intricate Western technologies, such as guns. The Japanese nobles were especially impressed by the clock mechanism, which made a great impact on Japanese craftsmen. In the 17th century, Japan entered a period of isolation during which all cultural and social exchanges with outside countries were completely cut off, a policy that continued until the mid-19th century. These 260 years of isolation were generally peaceful, and most people enjoyed their everyday lives, regardless of social class. This time set the stage for the major technological advancements that lead to the creation of uniquely Japanese karakuri.

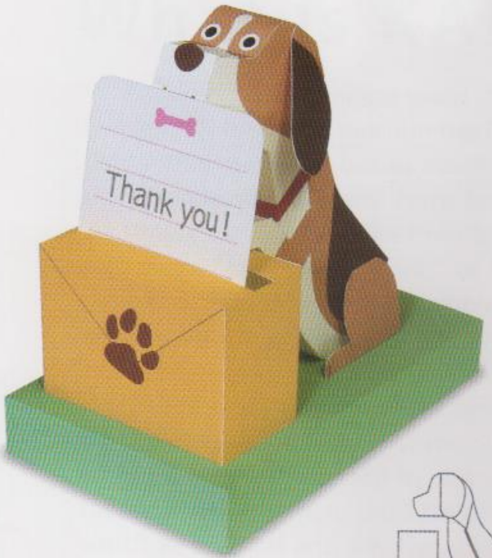
One particular characteristic of Japanese karakuri is that they incorporated popular mechanisms not for practical industry or engineering, but for entertainment and amusement, parade floats, theater, and toys. These types of karakuri were enjoyed not only by the upper classes but also by common people. But in order for a toy to be loved and enjoyed every day by common people, it needed to display much more than just accurate movements; a toy also needed fun and playful characteristics to amuse the audience.

One classic karakuri toy that did this was "Chahakobi Ningyo" (illustrated above), which means "tea-serving doll." A doll is carrying a tray on its arms, and when you put a teacup on the tray, the doll moves to the guest being served. When the cup is lifted, the doll stops; after the guest enjoys the tea and places the empty cup on the tray, the doll makes a U-turn and brings the cup back to the server. It was a delightful little toy with a charming act. Another famous karakuri toy is "Yumihiki Douji," which means "bow-bending boy." This doll bends a bow and shoots arrows at a target one after the other, missing the target every few shots or so, which adds to the humor of the action.

During the 18th and 19th centuries, Europe also saw a boom of karakuri-type toys, called automata. Japanese karakuri toys at that time lagged somewhat in terms of precision and materials, due to the long isolation from European influences. On the other hand, these limitations may have been the key factor in the birth and development of Japan's original karakuri, designed with certain restrictions but still imaginative and charming enough to make people smile at a neatly crafted toy.

# 1

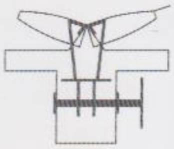
# Karakuri Gallery




## Good Boy!

**Lever**

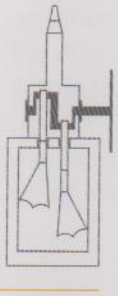
This obedient puppy will always sit on your table, waiting for you. Push down his tail, and he will lift his head to reveal a message for the family. You can make your own message card and customize the message.



## The Last Resistance

**Cam A**

Poor fishy struggles at the last moment of its life, before it is turned into delicious pieces of sushi. The up-down movement of two cams at the center of the fish mimics the side flops of a live fish.



## Below the Surface

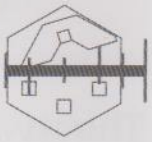
**Crank A**

Perhaps you never realized that even the most graceful swan frantically paddles its flippers under the water. Two bent cranks are hidden inside the body of this swan to create this movement.

## Hesitation

**Crank B**

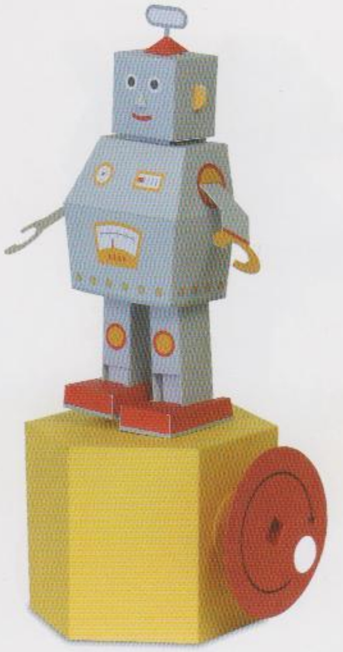
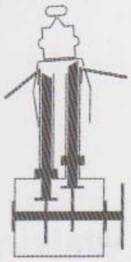
He'll never have the courage to test his new flying machine—he keeps holding back at the last moment. That's because a linkage between the toes is fixed to the base and the turning rod of a crank.

## Maternal Dilemma

**Cam B + Cam C**

Mommy's got a dilemma—all of her babies are starving. Which one shall she feed first? The babies move up one after the other on three separate cams, and the mother swivels using two cams on the ends.

## Teeter Totter

**Cam B**

The classic tin-toy robot walks on two feet like a small child. Arms are attached to the top of the rods of the two cams, which is why they move up and down in conjunction with the legs.

## Warming Up for Xmas

**Cam A**

You know everyone is busy just before Christmas, even a reindeer—Noel's getting ready to run a marathon to shed a few pounds. The body moves up and down on a cam, with a coin placed inside as weight.


## The Golden Rule

**Cam A**

These three wise monkeys move by cams of the same shape, but each linkage results in a different movement. You can take them apart individually, change the order, or change the rhythm of each movement.

## Walking Beagle
by Meeko

**Gear A**

The two upper gears mesh with the gears on the base, and each gear works as a crank to move the beagle's legs. The gears are exposed and brightly colored to accent this fun piece.

## Thirsty Dinosaur
by Mizuki Noguchi

**Gear A**

The dinosaur's neck moves up and down to drink from the water pool as the gear turns. What a unique idea to expose the teeth of the gear and turn them into the plates on the back of the stegosaurus!

## Cutie Elephant
by Sayuri Akagi

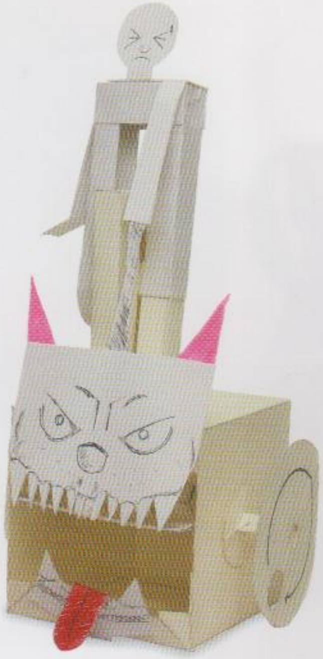
**Crank B**

The rod that moves on a link system becomes the trunk of this cute elephant. Unlike a cam, a crank can still perform the same movement when laid sideways, and this piece does just that.

## Come, Come Cat
by Miho Iino

**Crank C**

This lovely cat entices its prey with a luring paw. Poor thing—the panicky mouse keeps spinning round and round with nowhere to go as the axle holder on the other side of the handle rotates.



## Walking a Mad Dog

by Shunsuke

**Crank C**

The whole base of this piece is the body of the dog. The owner of the dog jitters up and down, while the rampaging dog at the end of the leash masticates violently as the cam on the crank rod turns.

## Flying Fish

by Kazuyoshi Mori

**Cam B**

Fly, fish, fly! This jumping movement may be more easily expressed with a crank, but this piece is cleverly designed as a cam, with the thin bamboo and string working as a link between the two rods of a cam.

## Chiming Penguin

by Kaho Fujimaki

**Cam C**

A musical penguin chimes the bells he holds by flapping his wings. The faster you turn the handle, the more noisily he plays. This special piece is the only one here that incorporates sound.

## Dolphin Show

by Rio Kazama

**Cam B**

Two dolphins take turns jumping out of the water to knock the hanging balls. The waves that hide the rod system and the framework from which the balls hang give this piece a real feeling of a classic toy.

## Broken Pedals

by Kana Ariga

**Gear A**

The two legs of this man are attached to the turning wheel at a slightly off-center spot. The way the ankles, knees, and waist move on a crank gives this piece real humanlike movement.

## Serious Sword Fighters

by Shiro B.

**Cam D**

As the rod goes sideways back and forth, two Japanese sword fighters go to and fro without lifting their heels, keeping a suitable distance between each other. The one who makes the initial move will win.

## Hit the Moles!

by Reiko Okuma

**Cam B**

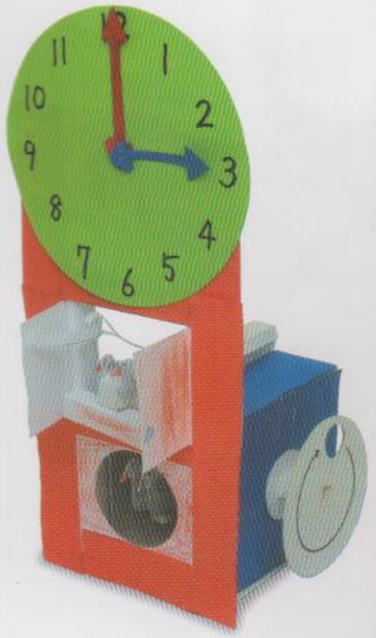
The moles popping up and the arms trying to hit them are linked to two rods inside that move up and down alternately. The intricate mechanism inside is unimaginable from the piece's comical appearance.

## Yes, You Can Do It!

by Shiori

**Geneva Stop**

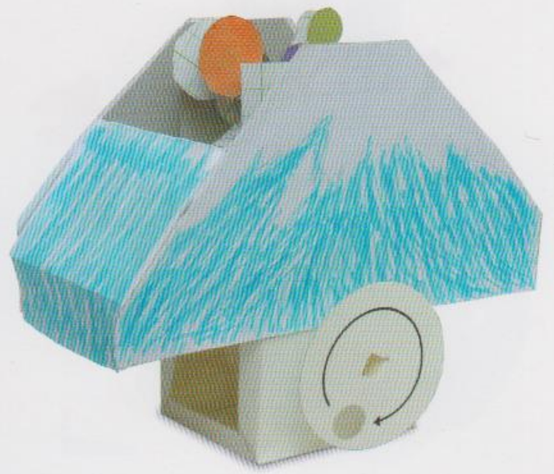
For every full turn of the handle, only $\frac{1}{6}$ of the wheel turns, pushing up the feet of a girl on a horizontal bar. The irregular movement shows her strenuous physical effort, though she never makes it over.



## It's Time for a Break! by T. Ishida

**Cam D**

Cuckoos pop out of the clock to let you know it's three o'clock. The lower one pops out from the display stand itself, using the movement of the frame inside. The way the doors close on a string is also very smart.



## A Day in Japan by S.W.

**Geneva Stop**

The sun and moon alternately overlook Mount Fuji. They pop up as they hit the tips of the wheel inside, and then disappear again. The irregular movement of the solar bodies represents a day in fast motion.

## Kite in the Dusk by Ririko Fujishima

**Crank A**

This is a very poetic piece. A boy flies a kite, standing in a field and reaching his arm up high. As the kite sways back and forth in the orange sky, you might find yourself reminiscing about memories of childhood.

## Fish in the Ocean by Marie Ueda

**Gear B**

Images of various fish are collaged on a cylinder attached to a horizontal gear. Looking through the windows fixed on the display stand, it feels as if you're on an excursion to an aquarium.

## A Pirate Ship
by Sachi Otomo

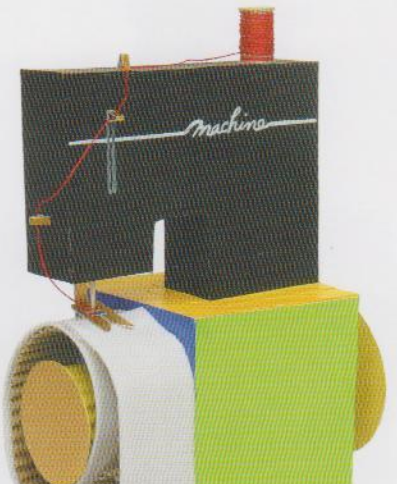
**Crank A**

A ship of brave pirates navigates through the stormy sea as it wildly sways on a crank. A wooden stick is put through the rod (also used as the ship's mast) to strengthen the rod and the display stand of this piece.

## Boat's in Danger!
by Satomi Sakurai

**Crank B**

A rowboat is nearly overturned by the large wave, but the man rides it out every time. The inside of the display stand is painted to resemble deep ocean, and the cellophane is a clever expression of the crashing wave.


## Space-Traveler Bicycle
by Hashimoto

**Geneva Stop**

A bicycle made of wire turns its pedals as tips of a Geneva stop hit the central disk. As the pedals irregularly turn, it amost looks as if an invisible man is in the empty seat, trying to move this heavy bicycle forward.

## Old Sewing Machine
by Aya Okada

**Cam A**

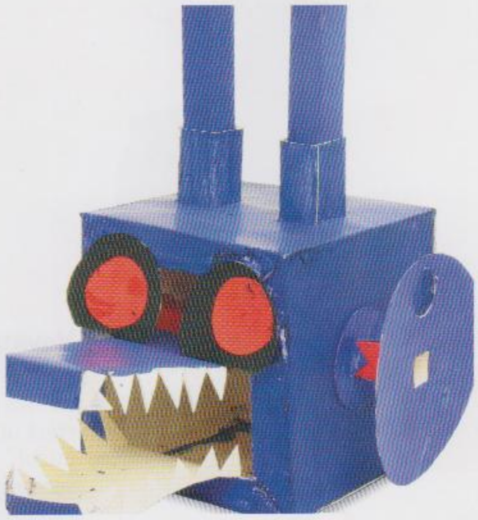
You can hear the click-clock as the needle moves up and down on a cam and the fabric slides forward using the rotation of the bearing inside. A very nice use of zigzagged cardboard causes more friction.

## Wandering in the Sky

by Tetsuya Ito & P. Crafter

Cam B

Here, two cams with separate handles are attached next to each other. As the two handles are turned simultaneously, the red dragon begins to wander about high up in the sky, right above the cotton clouds.

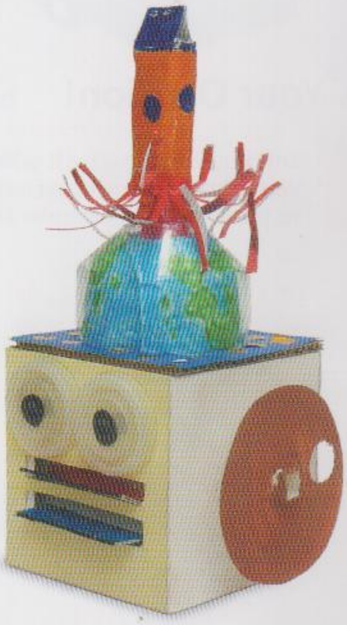


## Karakuri Dragon

by Fujiwara

Cam B

The dragon moves its horns up and down and chomps its mouth as the upper jaw is pushed down inside the display stand. With a handle as the ear, this piece takes full advantage of one karakuri mechanism.



## Karakuri Alien

by Maccin DaVinci

Cam A

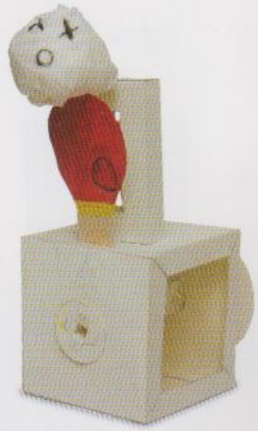
Just by looking at this, you may guess that the rocket will simply pop up, but that's not all—the lips of the alien move, too! Parts of a plastic bottle and film-case lids give this piece an alienlike texture.

## I'm a Hungry Snake!

by Erina Suzuki

Crank B

This snake looks like it's either raising its head and sticking out its tongue or widely opening its jaws. The camouflage pattern adds to the peculiar and mysterious feeling of this piece.



## Uppercut!

by Hayato Mori

**Crank C**

The glove attached to the rod hits the opponent's jaw, throwing a perfect uppercut. Just look at the guy's face—ouch!

## Guitarist

by Shota Fujimori

**Cam B**

A thumbtack is used to transmit the rods' movement to the hand striking the guitar strings. Notice—it's a Gibson Firebird!

## A Kettle

by Okuyo Yokokawa

**Crank C**

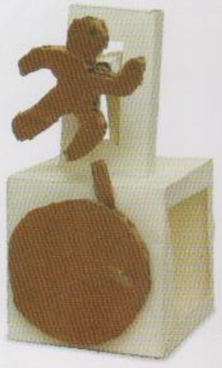
No matter how far the kettle is tilted, not a drop pours out—it's all in vain. Its being so nicely crafted adds to the humor.

## Tell Us Your Opinion!

by Shimodori

**Cam B**

This guy won't back off with the mic until you speak. The arm could have been moved to the side, but it's funnier this way.

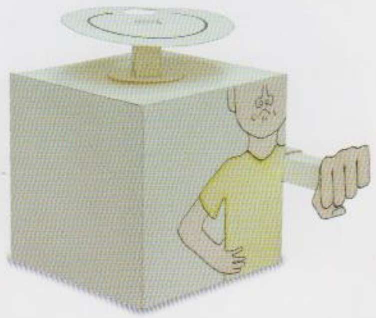


## I'll Keep Running Forever

by T.S.

**Crank C**

The smiling runner jumps over the obstacle on the disk attached to the bearing inside—he just barely makes it!



## An Angry Person

by Ayaka Tomozumi

**Cam B**

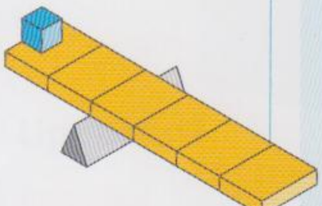
This person is so angry with you he won't stop punching at you, but the slowness of his fist just makes you want to laugh.

# 2

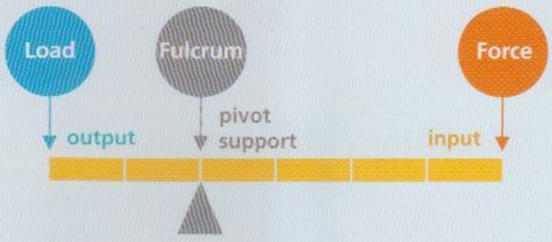
# How Karakuri Work

# Lever

**A lever is one of the oldest mechanisms invented by humans. A lever is a simple machine that can multiply an applied mechanical force or change the direction of a force. Levers tend to go unnoticed because the mechanism is commonly used in almost every tool and machine.**

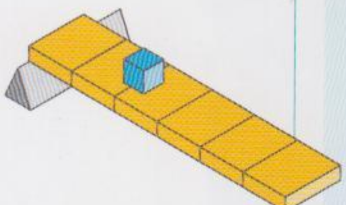


## 1st-class lever | small force turns into BIG force

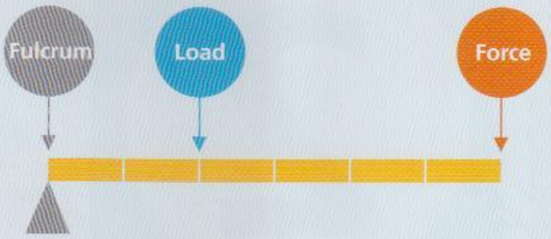


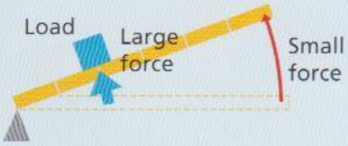


By exerting a small force over a great distance, a larger force is exerted in the opposite direction.

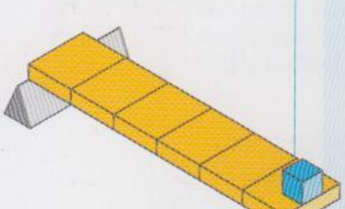


## 2nd-class lever | small force turns into BIG force

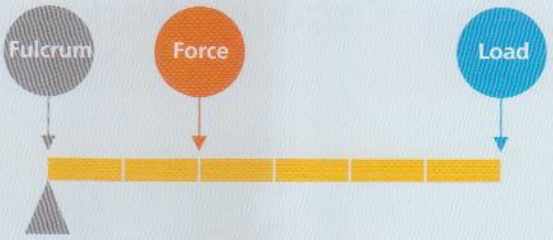



By exerting a small force over a great distance, a larger force is exerted in the same direction.



## 3rd-class lever | BIG force turns into small force





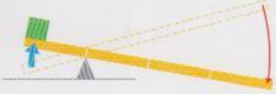
The input force is larger than the output. Output load is smaller but exerted over a greater distance.

### How a lever works

When you're lifting a load, there is a law of physics in the relationship of the distance between the fulcrum and the force and the amount of the applied force. The longer the distance, the less force is needed. For example, if you the double the distance, the force decreases to $\frac{1}{2}$, and triple the distance, the force decreases to $\frac{1}{3}$, and so on. This is called the "lever mechanism." But if you want to lift the weight to the same height, the force must be applied over a greater distance—double, or maybe triple.

Without a lever
- Needed force = the load
- Distance of force = distance load is moved

Distance bet. fulcrum + force is double that bet. fulcrum + load
- Needed force = $\frac{1}{2}$ the load
- Distance of force = 2 x the load



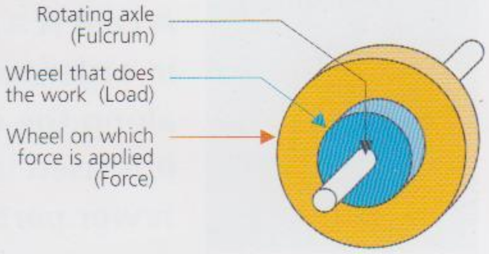
Distance bet. fulcrum + force is triple that bet. fulcrum + load
- Needed force = $\frac{1}{3}$ the load
- Distance of force = 3 x the load

### Let's make it & try!

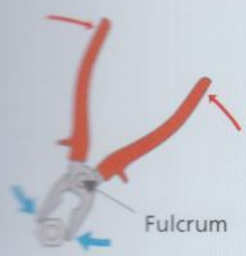
A lever karakuri model is not included in this book. But the handles of all the models use a wheel axle, which is a variation of a lever. Look for this and other functions in the models that use the lever mechanism to change the size or direction of a force.

## Lever and wheel axle

A wheel axle is a set of two wheels of different sizes that rotate on the same axle. If you think of the axle as the fulcrum and the edges of the wheels as load and force, you can see that this is actually a 2nd-class lever. The steering wheel of a car, the grip of a screwdriver, and the handle of a faucet are some examples of this type of lever. By using the lever mechanism, the wheel axle can turn a central axle that is otherwise difficult to turn.



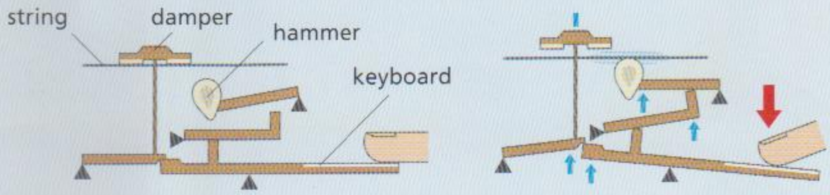

### Pliers



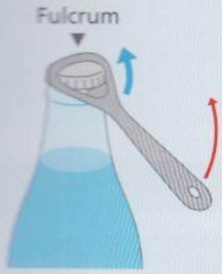

### Crowbar


### Piano

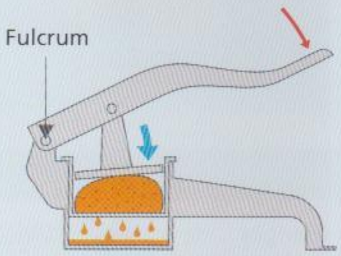
Inside a piano, the force applied from the fingers hitting the keys is transmitted through a number of levers and lifts the felt-tipped hammers, which hit the strings to make beautiful sounds. The same force goes through a different lever to release the damper that is pressed against the strings. The pipe organ and electric piano work differently, of course.



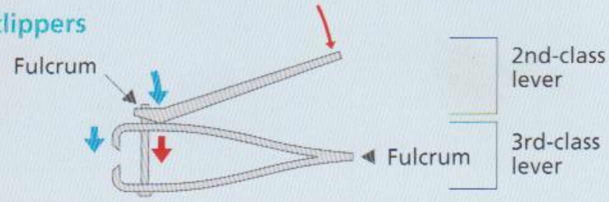

### Bottle opener




### Hand-press juicer

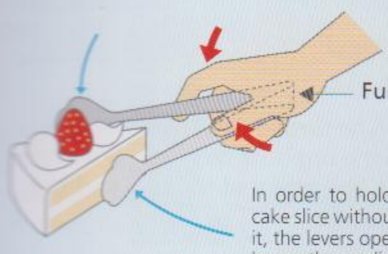



### Nail clippers



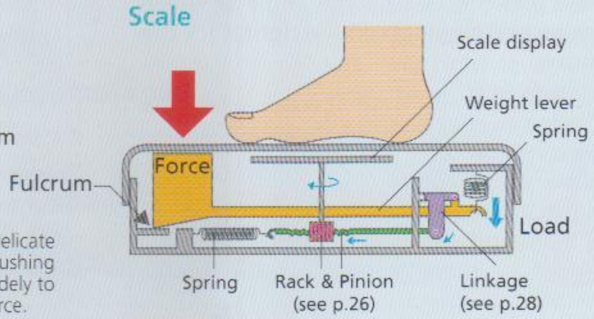

Nail clippers are a combination of two different levers. The upper lever multiplies the force from the finger and transmits it to the sharp-edged lower lever. Because the distance between the force and the load on the lower lever is very close, not that much force is required to move the load. This is why you can cut through a hard, thick nail with just a gentle push of your fingertip.

### Cake tongs




In order to hold a delicate cake slice without smushing it, the levers open widely to lessen the applied force.

### Scale




A scale measures weight by using the spring's ability to stretch. But instead of using a spring that can hold hundreds of pounds of human weight, a scale uses a 3rd-class lever to change weight into a force much smaller that small springs can hold. When the springs stretch, the weight lever goes down, and then the force goes through a linkage and a gear to rotate the scale display. A scale is made up of four of these levers, so that weight can be measured accurately by standing on its center.

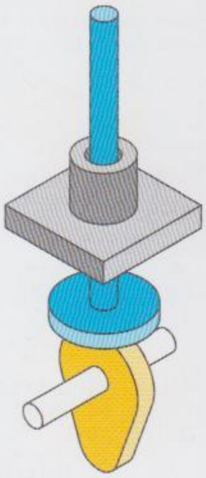
### Could Archimedes Lift the Planet Earth?

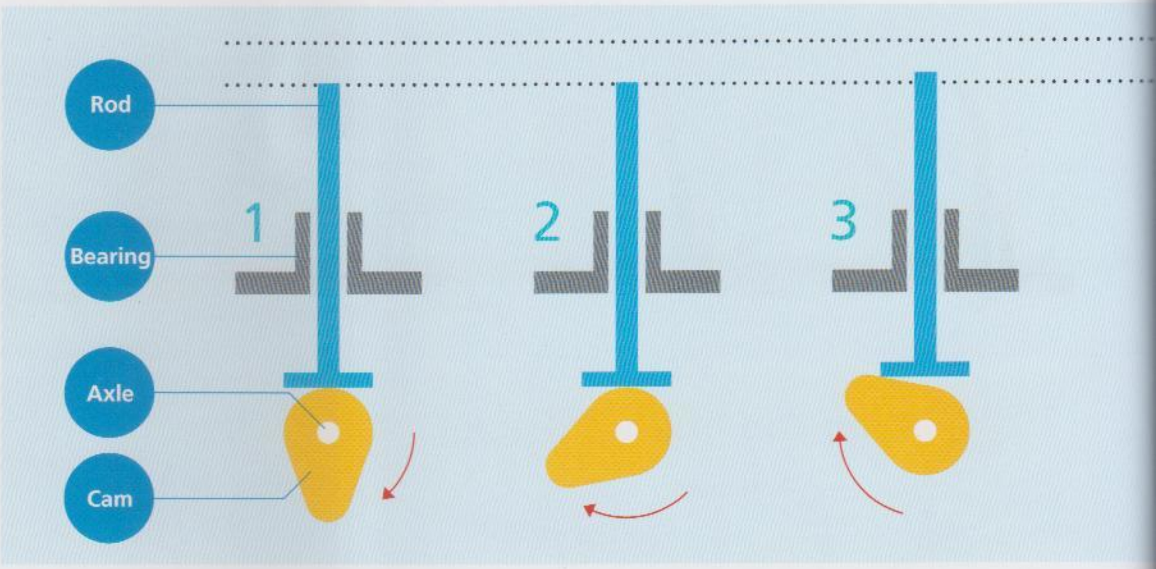
Archimedes was a Greek scientist who lived in the 3rd century B.C. and designed many machines and weapons people at that time used. He was the one who first defined the laws of the lever, though the lever mechanism had been used in practice for some time. One of his famous quotes is "Give me a place to stand and I will move the earth!"

But could earth really be lifted by a lever? If so, how long would it need to be? Well, let's think of the moon as fulcrum and the sun as force. The distance between earth and moon is 237,700 miles, about 400 times more than the distance between earth and sun, so the force needed is only $\frac{1}{400}$ of earth's weight. The weight of the earth is approximately 6 trillion tons (6 with 21 zeros after it—can you imagine?), so even $\frac{1}{400}$ of that is a lot: 15 with 18 zeros after it. Even if the handle of the lever could be stretched to the far end of the universe, you would still need thousands of tons of force to lift the earth. So even Archimedes may not have been able to lift the earth, after all.

# Cam

**A cam is a mechanism that turns or moves variously shaped disks in order to change the direction or rhythm of how parts move along the contour of those disks.**
**It is used in many machines to make intricate movements with fewer parts, just by changing the shape of the disk.**






### Let's make it & try!

**Cam A**
The rod makes a repetitious vertical motion.
**Instruction: p.36**
**Model: p.65–67**

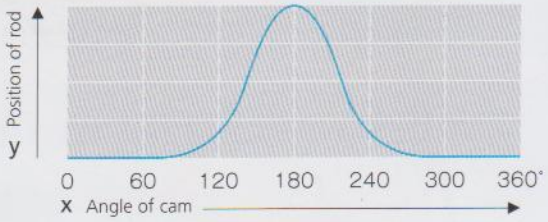
**Cam B**
Two rods make a vertical movement alternately.
**Instruction: p.37**
**Model: p.69–71**

**Cam C**
The rod makes a repetitious horizontal movement.
**Instruction: p.38**
**Model: p.73–75**

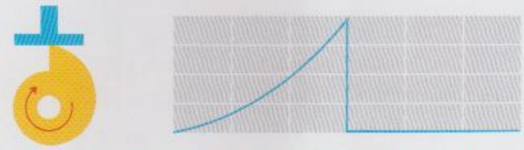
**Cam D**
The rod slides repeatedly in a linear motion.
**Instruction: p.39**
**Model: p.77–79**

## Various cams and how they move

You can see how the shape of the cam changes the way a rod moves by taking a look at these graphs, in which the y-axis is where the tip of the rod is and the x-axis is the angle at which the cam turns. The graph on the right is for the cam above.

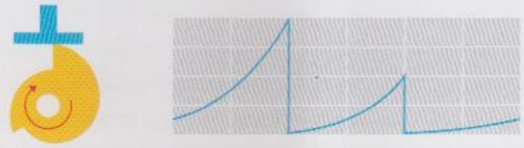



Cam B (two identical cams moving in different directions)

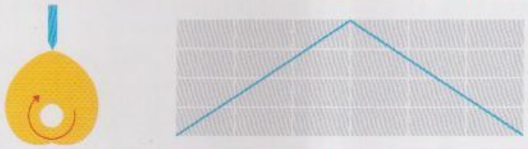


This cam can be turned only in one direction. If turned in the opposite direction, it will get stuck on the projection of the cam and stop.

Cam A

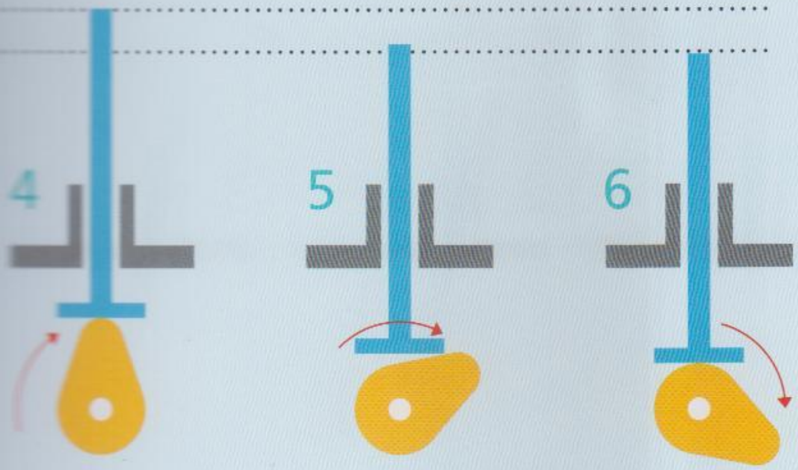


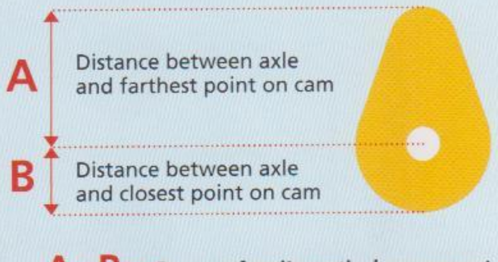
Every time the cam turns, the rod goes up and down twice. In this cam, the first movement is different from the second.



This cam, sometimes called a heart cam for its shape, is used to move the rod at exactly the same speed every time.


The mountain-shaped cam goes back and forth sideways to move the rod vertically. This results in a symmetrical pattern of rod movement, as you can see on the left.



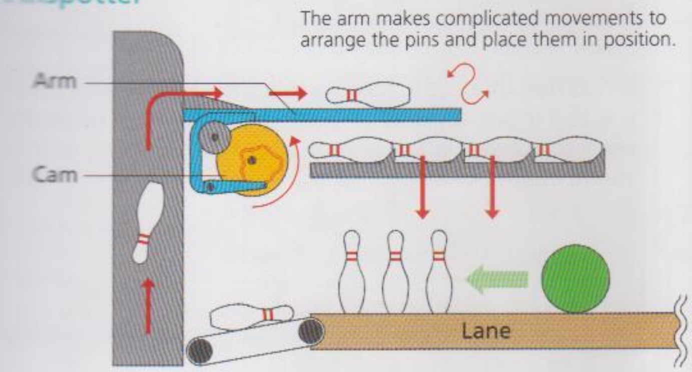




**A–B= Range of rod's vertical movement**

For every turn of the cam, the rod goes up and down once. The range of the vertical movement of the rod depends on the distance between the axle and the edge of the cam. By changing the shape of the cam, you can make the rod go up and down many times for every turn of the cam, or make the rod go up and down at more complicated intervals.

## Where cams are used

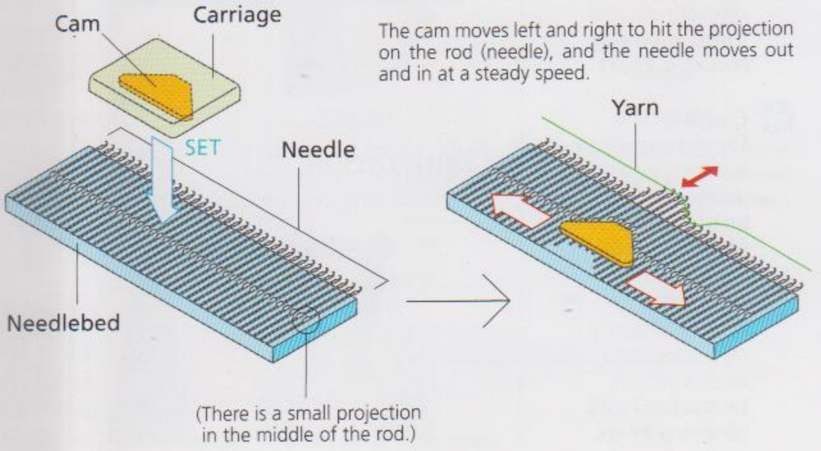
### Pinspotter




A pinspotter is a very important machine at any bowling alley, collecting all the pins hit by the ball and rearranging them for the next set. Inside the pinspotter, there is actually a cam, on a very intricate guide rail. An arm that corresponds to the movement of the cam goes up, down, left, and right to arrange the 10 pins in the right spot every time. This complicated machine, which has other functions such as collecting the balls and pins remaining on the lane, was invented in the USA about 60 years ago, and its invention made bowling explosively popular. Before pinspotters came about, there were "pinboys" in every alley who would pick up all the pins and rearrange them by hand.

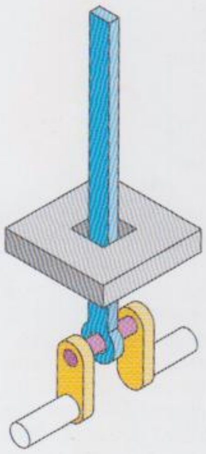
### Knitting machine or loom

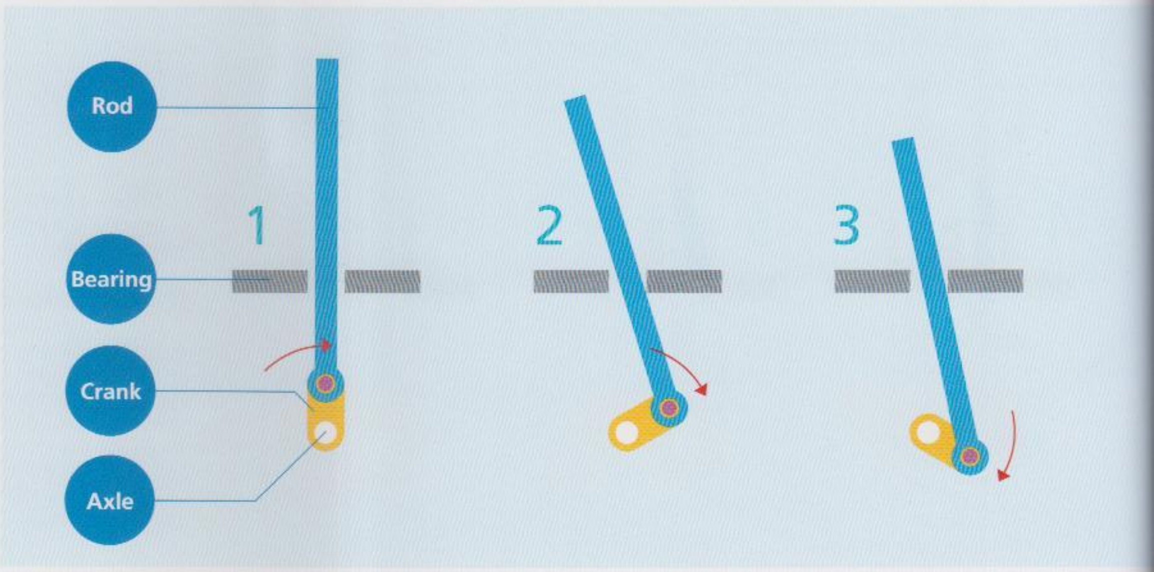
A knitting machine works by using a number of needles to catch yarn to knit into a fabric; a cam is used to do that. The cam is placed inside a carriage device and set on a row of horizontally aligned needles. Every time the cam touches the projection on the needles, the needles are automatically pushed out one after the other. Back in the days before computers, looms had specially designed cylinders with projections at the tip of the needles that turned to select only the needles that corresponded to a particular carriage, which is how patterns were made. This is also a variation of a cam.



# Crank

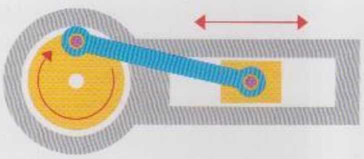
A crank is a mechanism that uses a hook-shaped axle to convert a rotation into a linear motion, or, vice versa, a linear motion into a rotation. By combining a crank with a linkage, a very complicated motion can be produced.






## Various cranks and how they move

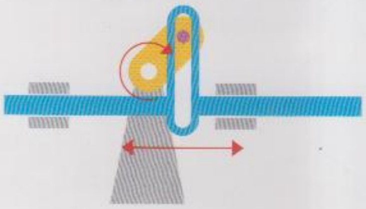
### Slider-crank



A rotation of a crank is converted into a linear motion of the rod inside a cylinder. This type of crank is generally used to convert a linear motion into a rotation, as in a steam engine or a car engine.

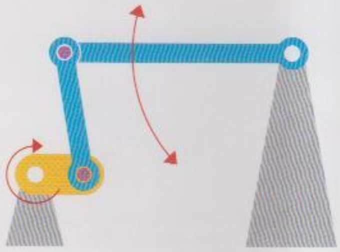
➔ Crank C

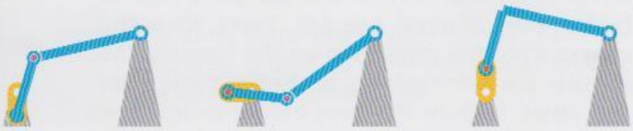
### Cross-slider crank



A pin inside a groove moves up and down to turn the crank itself. Because the vertical range of the pin's movement equals the horizontal range, the vertical movement of the crank's rotation is neutralized. As a result, the rod moves only in the horizontal direction.

### Crank rocker





An arm attached to the rod converts the rotation of the crank into a vertical swinging motion. Sewing machines with foot pedals and bicycle pedals are examples of the opposite conversion, swinging motion into rotation.

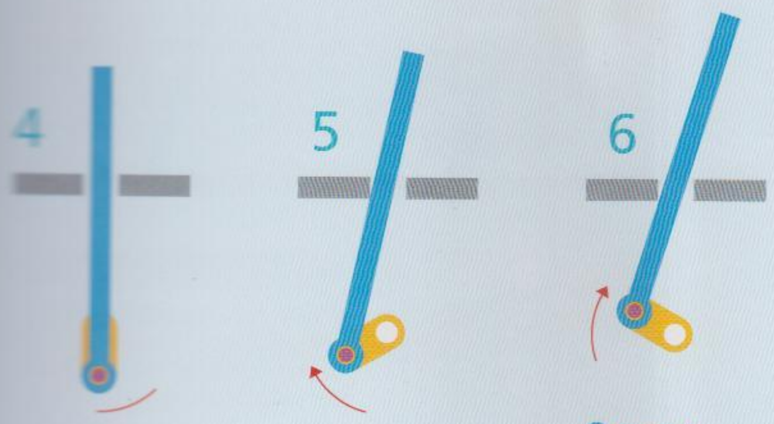
➔ Crank B

**Let's make it & try!**

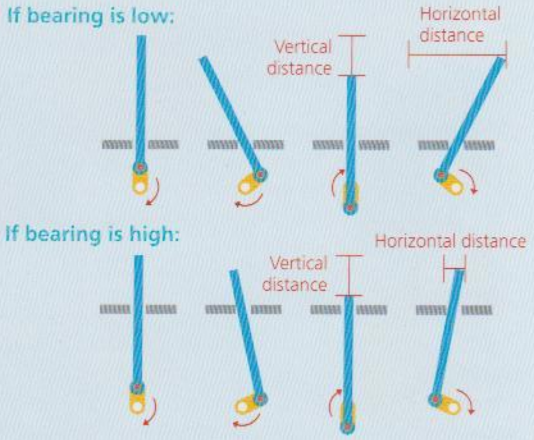
➔ **Crank A**
The rod sways repeatedly in a circular motion.
**Instruction: p.40**
**Model: p.81–83**

➔ **Crank B**
The rod sways back and forth by a linkage mechanism.
**Instruction: p.41**
**Model: p.85–87**

➔ **Crank C**
Turns of a crank is converted into a vertical motion.
**Instruction: p.42**
**Model: p.89–91**




➔ Crank A

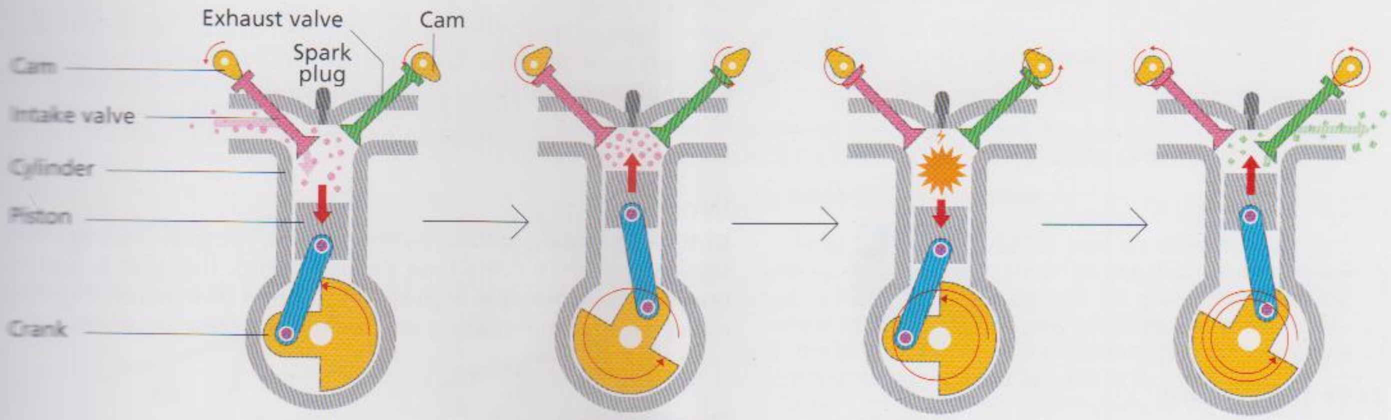



Vertical range of the rod's movement is fixed for all crank sizes, but horizontal range depends on the distance between the axle and the bearing.

## Where cranks are often used

### Internal Combustion Engine

A car is one of the most commonly used machines in our daily lives, and its internal combustion engine uses various mechanisms, including cam and crank. The engine usually works in a four-stroke cycle, also known as an Otto cycle: intake, compression, power, and exhaust. In one full four-stroke cycle, the crank and the piston make a full movement twice, of rotation and linear motion, respectively.




**Intake**
The cam opens the intake valve, and fuel and air are taken into the cylinder.

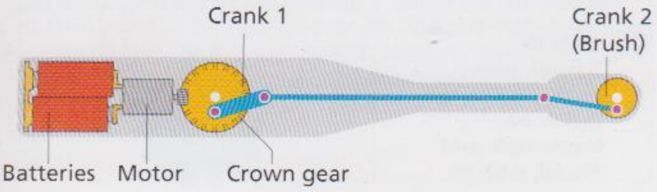
**Compression**
Two valves close, and air inside the cylinder is compressed by the piston.

**Power**
The spark plug ignites a fuel-air mixture, and the explosion pushes the piston down.

**Exhaust**
The piston comes up again and pushes out the exhaust gas through the valve.

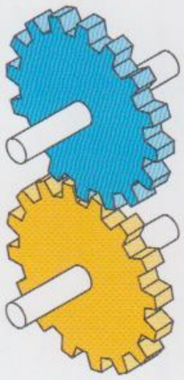
### Electric toothbrush

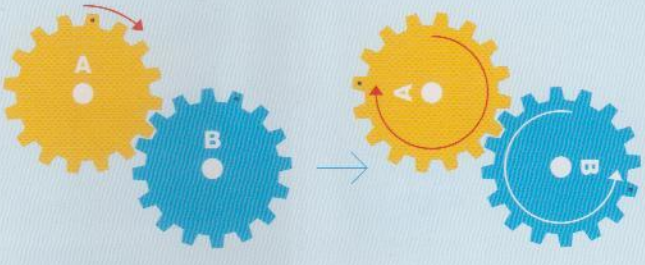
For those types where the brush rotates at the tip, the rotation of the motor converts to the rotation of the brush using two cranks. Small gears at the tip of the motor, called pinion, or crown gear, function the same way as the bevel gear on p.26, converting the rotation into a third dimension.



# Gear

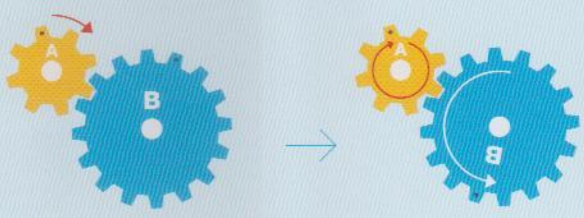
**A gear is a mechanism used in things we all know, such as a watch or a bicycle. It can change the direction of rotation, as well as the speed and amount of force. Gears can engage with not only other gears, but also a chain or a belt to exert force over a distance.**






**Gears of the same size**

If two gears have the same number of teeth, gear B makes one rotation for every rotation of gear A. The speed of the gears is the same—only the direction changes.



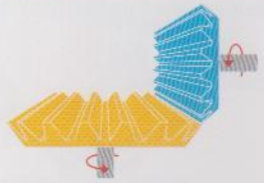

**BIG gear & small gear**

If gear A has half the number of teeth as gear B, B rotates only half a cycle with a full rotation of A, so the speed is also reduced by half.

➔ Gear A

## Various gears and how they move

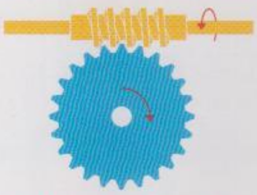
The gear above left is called "spur gear" and is probably the most common type. There are other kinds of gears used in machines, made in various shapes and engaged in various ways.



### Bevel gear

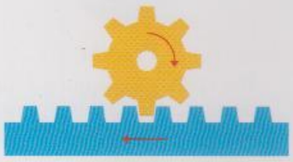
In this type of gear, two conically shaped gears intersect perpendicularly or at an angle to each other. This mechanism can convert a two-dimensional rotation into a three-dimensional motion.

➔ Gear B (This mechanism is used for regular gears engaged at a 90° angle.)



### Worm gear

By turning an axle with screwlike grooves, the gear is turned very slowly (one tooth every time the axle turns). This gear is used to quickly slow down the high-speed rotation of a motor. It got its name because the rotating axle looks like a crawling worm.



### Rack and pinion

A small gear (pinion) engages the teeth on a flat bar (rack) that moves in a linear motion. Vice versa, the pinion can be rotated by moving the rack. This mechanism is used in camera tripods.

### Planetary gear (or sun and planet gear)

The axles of two gears of different sizes have been attached by a free-moving arm, resembling a planet (small gear) orbiting around the sun (large gear). This unique mechanism makes a complicated movement of rotation and revolution, used in amusement-park teacup rides and wall-mounted pencil sharpeners.

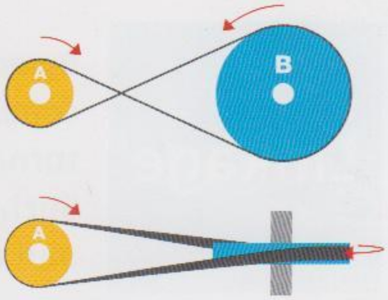
**Let's make it & try!**

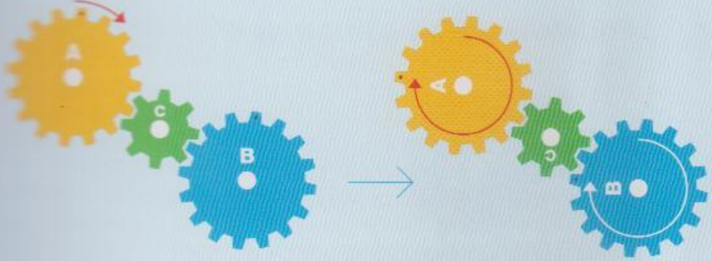
➔ **Gear A**
The gear turns horizontally to the handle.
**Instruction: p.43**
**Model: p.93–95**

➔ **Gear B**
The gear turns perpendicularly to the handle.
**Instruction: p.44**
**Model: p.97–99**

### Gear and pulley

The angle or direction of gear rotation can be changed by using a belt made of materials like rubber instead of a chain. The gears on top are engaged by a criss-crossed belt, and the ones below are engaged by a belt turned sideways. Belts cannot be placed directly on gears, so various adjustments are made to gears used in real machines in order to keep the belt from slipping off the gears.



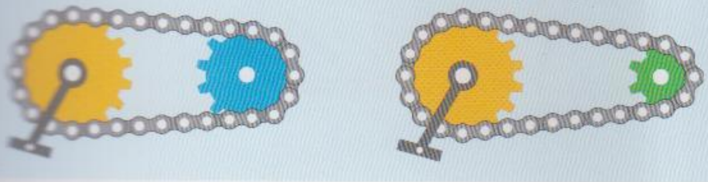




### Multiple gears

If a small gear C is placed between A and B, the direction of B stays the same as A. Gears A and B in the left picture have the same number of teeth, so the speed of A and B are the same, regardless of the number of teeth of C, but the direction and speed of rotation can be readily changed by engaging a number of gears of different sizes.

**Paired with a large gear**
Pedals are *light*, but gear moves slowly.

**Paired with a small gear**
Pedals are *heavy*, but gear moves fast.



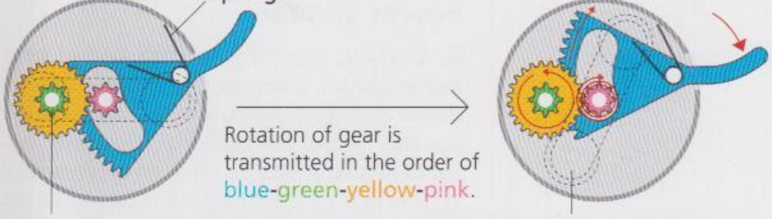
### Gear and chain

If the axles of two gears are far apart, they can be engaged using a chain. A bicycle is a known example of this. How the gears are engaged influences the required force and speed of the pedals, so the speed of the bicycle changes depending on the gear, even if you apply the same force.

## Where gears are also used

### Bicycle bells

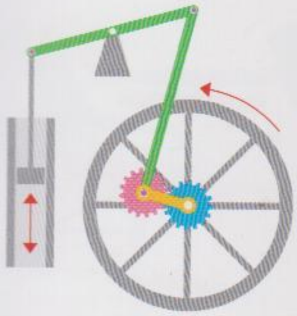
You've probably seen those bicycle bells that ring when you pull a little lever. Inside, there are four gears of various sizes. When the lever is pulled, it is automatically pushed back by a spring, and one full movement of the lever is magnified by the gears into several rotations of a bar on top with metal on each end, which strikes the bell to make a loud ringing sound.



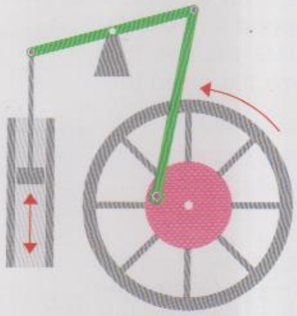

The green gear is underneath the yellow and meshes with the blue.

There is a bar with two metal ends that rotates on the same axle as the pink gear.

## Is Pride the Mother of Invention? The Planetary Gear of James Watt



Watt's design of the planetary gear that converts the piston's linear motion into rotation.



It would have been much easier to make it with a crank, as you can see above.

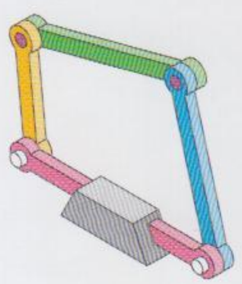
James Watt (1736–1819) was an inventor who first came up with a working steam engine that greatly contributed to the Industrial Revolution. He is also known as the inventor of the planetary gear, which he designed to convert the vertical motion in the steam-engine cylinder into a circular motion that could be used in factories.

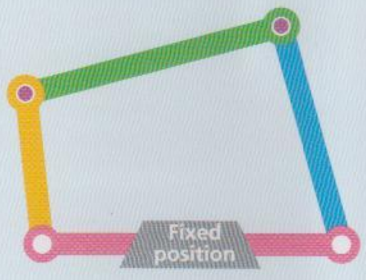
There's an interesting episode behind the invention of the planetary gear. At first, Watt's design was based on a crank mechanism commonly used at the time. But one day, an engineer who was working for Watt had too much to drink at a pub and blurted out all the secrets of their new project. When a factory owner who was at the pub heard it, he stole the idea and got it patented! Watt didn't want to pay the patent fee to use his own invention, so he decided to create an entirely new mechanism, the planetary gear.

Years later when the patent expired, most internal engines were changed to a crank mechanism, but various forms of the planetary gear are still used in many machines and tools today.

# Linkage

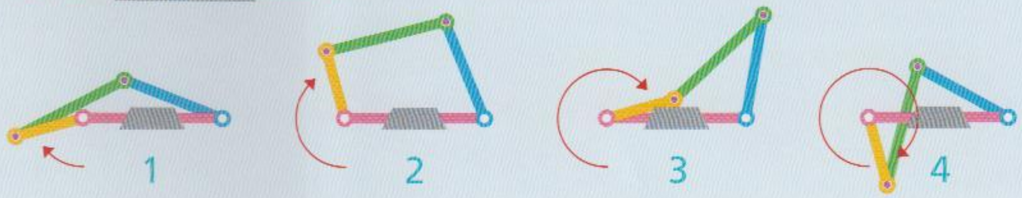
**By adding a few arms to link simple devices, combinations of linear and circular motion can be turned into various complicated movements. Such a mechanism is called a linkage, and most machines we use are made up of linkages.**






### Four-joint composition of basic linkage

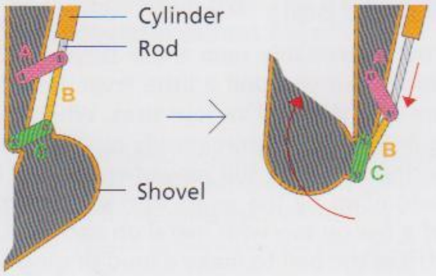
The image on the left represents the most basic form of linkage. Four arms are linked by four rotating joints, with only the pink arm on the bottom in a fixed position. If you rotate the yellow handle, the green and blue arms always make the same movements. These motions can be used in various tools and machines.
By changing the lengths of the arms or the motion of the joints, intricate movements can be created to suit the purpose of many machines. Linkages on the right page are made of the same four arms, but they make different movements depending on which arm is fixed in position.




## Where linkages are often used

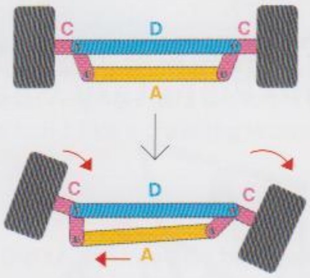
### Power shovel

By pushing the joint of arm A and arm B, arm C moves down. Because C is shorter than A, C swings down farther than A, which is how the shovel digs up dirt from the ground. Because a very large force is needed to do this, an oil-hydraulic pressure system is used, in which oil is poured into a cylinder to push the rod down.



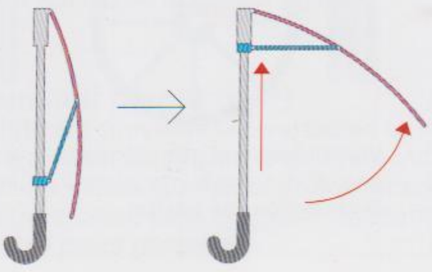

### Steering system of a car

The rotation of the handle is transmitted through a rack and pinion gear (see p.26) to arm A (tie rod). As A is moved to the left or right, arms C (knuckle arms) attached to the tires correspond in a circular motion. By making A shorter than D, the two tires tilt at different angles, which allows the car to turn street corners smoothly.




### Umbrella

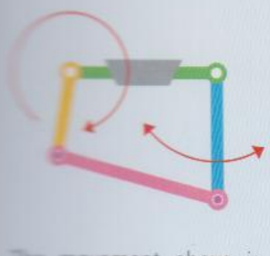
A linkage mechanism is used to open and close this common tool everyone uses. The image on the right is the most simple type of an umbrella mechanism. In an automatic umbrella (one that opens with a button) or a compact umbrella, another linkage connects to this basic linkage. If you happen to have an umbrella at home, take a look at it yourself.



**Let's make it & try!**

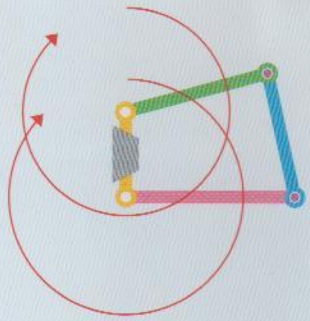
**Crank B**
The linkage makes a rod sway back and forth.
**Instruction: p.41**
**Model: p.89–91**

**Green arm is fixed**



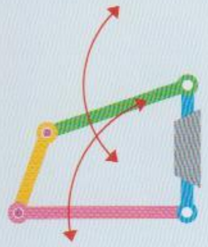
The movement above is pretty much the same as when the pink arm is fixed in position. Yellow rotates, and blue swings back and forth.

**Yellow arm is fixed**



In this case, both the pink arm and the green arm will make full rotations.

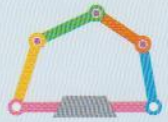
**Blue arm is fixed**



Here, the pink and green arms sway back and forth as the yellow arm rotates. This type of linkage can multiply the amount of a force using a lever mechanism.

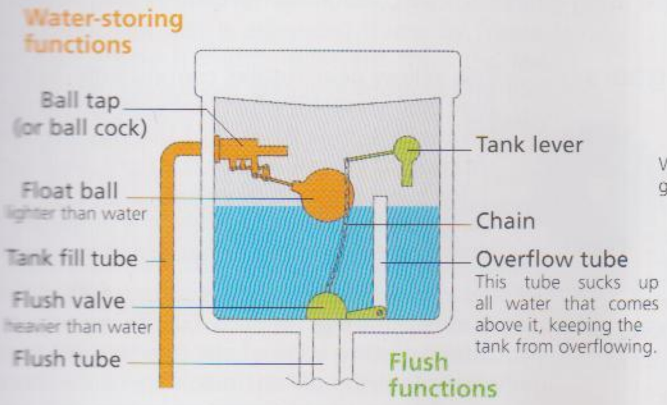
### What if the number of arms change?

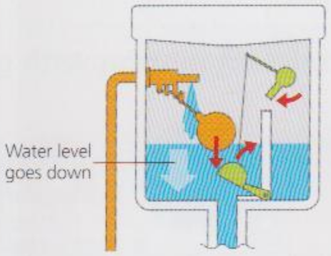
With only three arms nothing can move, so this form is sometimes used in architectural framework.



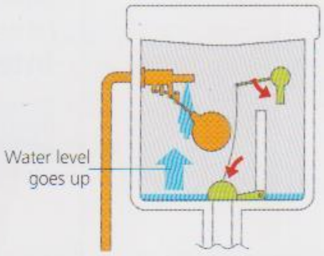
With five arms or more, the movement of the arms becomes unpredictable, so this linkage can't be used in a machine just on its own.

## Karakuri inside a toilet tank—can't live without it!

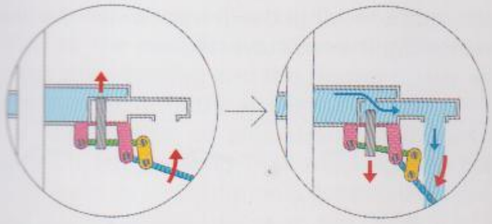



When the tank lever is pulled, the flush valve is lifted and water goes down the flush tube. The ball tap brings new water into the tank as the float ball sinks, but water drains so fast the water level goes down.




When the tank is nearly empty, the flush valve falls with its own weight, closing up the flush tube. As the water level starts to go up, the float ball closes the ball tap, stopping the flow of water into the tank.



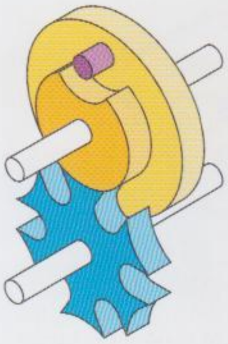
**Inside the ball tap**

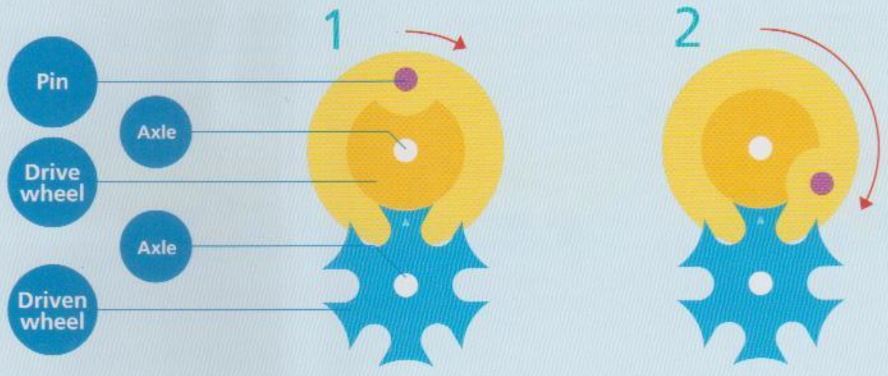
As the rod attached to the float ball moves up and down, the valve inside the ball tap opens and closes. From this image with colored parts, you can see that the ball tap is a four-joint linkage mechanism.

Did you know that the history of the flush-toilet system goes back quite a long time? Archaeologists have found 4,000-year-old ruins on the island of Crete that had flush-toilet systems with drainage and even a seat! The flush toilet we use today with chains and levers to release water from the tank was invented in late-19th–century England. Though invented during the time when there was not even electricity, the same basic mechanism is still used today, with some improvements and variations. The force of the finger on the lever engages various linkages and laws of buoyancy and gravity to flush out and fill up the tank at once. So next time your tank becomes broken, perhaps you can try fixing it yourself—just remember to stop the tank fill tube first!

# Geneva Stop

**A Geneva stop is a mechanism that converts a continuous rotation into a rotation that stops every now and then. It was given the name of the Swiss city of watchmakers, where it was first applied to springs inside watches; a mechanism similar to this is used in film projectors.**






A drive wheel with a crescent-shaped cutout begins to rotate. The "fin" of the driven wheel is aligned with the drive wheel.

The driven wheel remains stationary as the drive wheel rotates further.

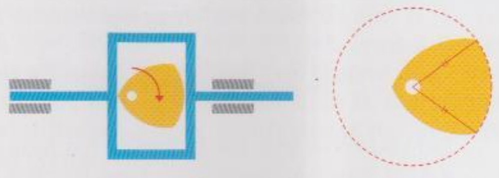
## Various mechanisms that produce intermittent motions

A repeated pattern of motion that moves, stops, and moves again is called intermittent motion. In order to produce intermittent rotary motions from the continuous rotations in most motors, a variety of mechanisms are invented using gears and cams, including the Geneva stop above.

### Intermittent motion with gears

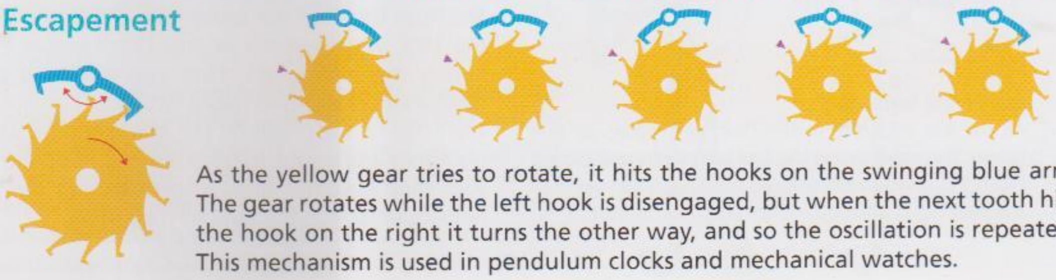
The yellow gear rotates continuously, but the blue gear stays still when teeth are not meshed. On the left, blue turns $\frac{1}{10}$ of the way for every rotation of yellow, and on the right, blue turns $\frac{1}{4}$ for every rotation of yellow.
Various intermittent motions are produced by changing the number or pattern of the teeth.

### Intermittent motion with cams



A cam rotating inside a frame moves a rod sideways. One edge of the cam is equal to the circumference of an imaginary circle drawn around the central axle, so when this edge is not touching the frame while the cam is moving, the rod stays still.

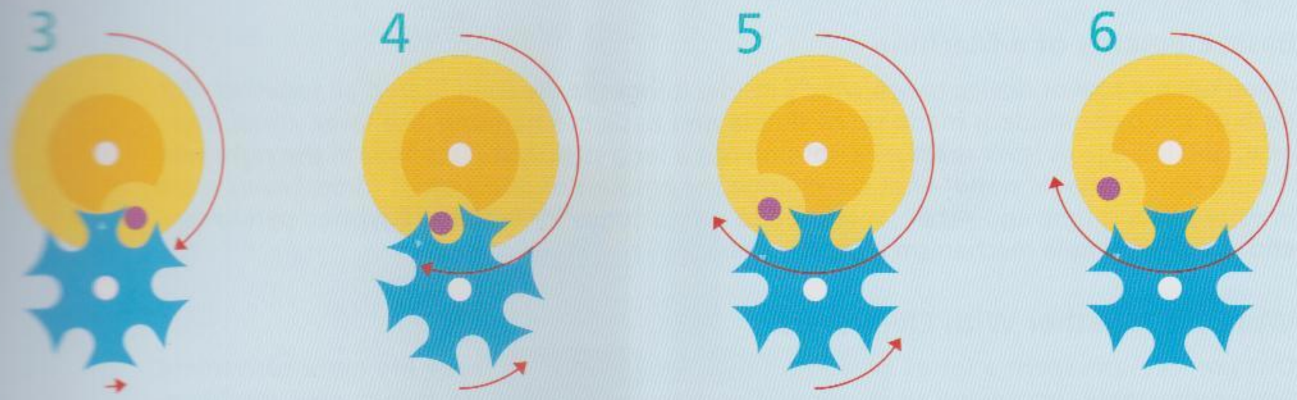
### Escapement



As the yellow gear tries to rotate, it hits the hooks on the swinging blue arm. The gear rotates while the left hook is disengaged, but when the next tooth hits the hook on the right it turns the other way, and so the oscillation is repeated. This mechanism is used in pendulum clocks and mechanical watches.

**Let's make it & try!**

**Geneva stop**
The wheel turns in a discontinuous rhythm.
**Instruction: p.45**
**Model: p.101-103**




The pin on the drive wheel slips into the slot, causing the driven wheel to rotate.

As the drive wheel rotates, the "fin" on the driven wheel passes through the part of the drive wheel where a crescent shape is cut out.

The driven wheel stops when the pin passes through, having turned 1 fin, or $\frac{1}{6}$ of a rotation.

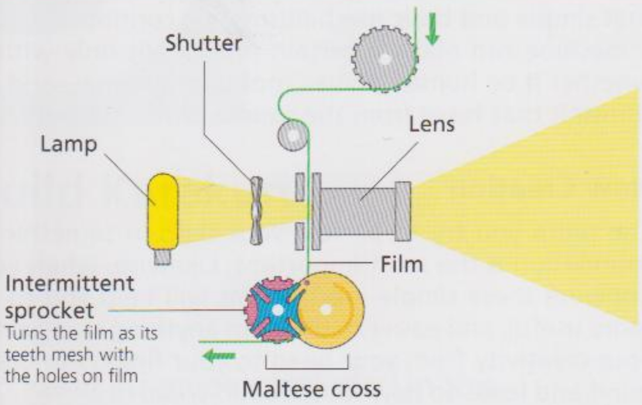
## Where intermittent rotary motion is often used

### Film projector

Movies work in the same way as flip-book animation. The film is advanced frame by frame, and each frame is slightly different from the last so that the human eye sees it in motion. The film looks like it's moving continuously, but it's actually in intermittent motion. Each frame stands still in front of the lens for a fraction of a second and is projected on the screen before the light is shut off and the film is advanced to the next frame.

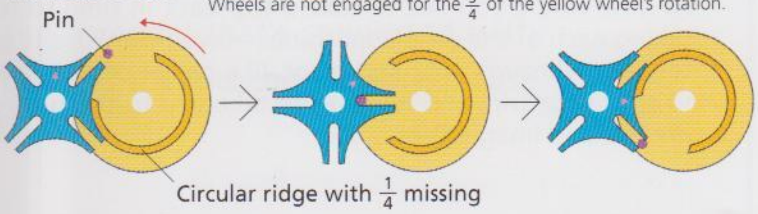
The mechanism that makes this happen is called the Maltese cross, a combination of two wheels, one with a pin (yellow wheel) and another in a cross shape (blue wheel). The yellow wheel continuously rotates via a motor, but the blue rotates only when the pin enters one of its slots and another gear on the same axle, called a sprocket (pink wheel), turns the film to the next frame. When the pin leaves, the cross stops turning and the shutter opens up to project the film onto the screen.

In a regular film or animation, 24 frames are projected each second. That means each frame stops in front of the lamp only for less than $\frac{1}{24}$ of a second (In the Maltese cross on the right, $\frac{1}{4}$ of the motor's rotation is used to move the frame, and it stays still for the remaining $\frac{3}{4}$ of the rotation, which actually makes it $\frac{1}{32}$ of a second.) At this fast speed, the human eye cannot detect the intermittence, so it just looks as if the film is continuously flowing and the picture is moving on screen.



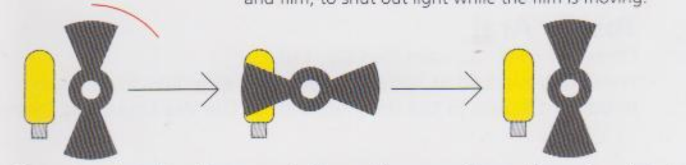

**Maltese cross**

The blue wheel turns with the yellow for only $\frac{1}{4}$ of the rotation. Wheels are not engaged for the $\frac{3}{4}$ of the yellow wheel's rotation.




**How a shutter works**

A propeller-shaped shutter rotates between the lamp and film, to shut out light while the film is moving.



A frame is projected. Film moves to the next frame. The next frame is projected.

# The World of Creation

Have you ever counted how many objects or tools you use every day yet you don't really know how they work? There are so many! If you stop for a moment and take a close look at the tool or device you're using, you may find yourself asking questions like "How does this work?" or "When was this invented?" Then, all of a sudden, you'll see that the world around you is much more interesting than you ever thought, full of things to discover and learn.

### Basic Elements of a Machine

If you open a tool or device to see what's inside, it looks really complicated all together. But each of the parts inside is made up of simple and basic mechanisms, like lever, crank, cam, gear, and linkage. A lever is actually nothing but a long stick, but if it's used in the right way it turns into a "magic wand" that can change the amount or direction of force. Levers were invented a long time ago—they were used to move stones for building Egyptian pyramids—and the same simple mechanism is used to this day.

### Working Together With Electronics

Our predecessors spent a lot of time using their imagination to make life more convenient and comfortable, improving upon simple mechanisms in order to invent new machines. During the past century, there have been extraordinary developments in mechanical and electronic technology that now enables us to send humans to outer space and use robots to assist our lives.

### Important Part of Our Future

No matter how advanced we become in electronic technology, there is, however, no doubt that simple and basic mechanisms will continue to play an important role. I say this because a machine can make a certain movement only with the application of an outside force—whether it be human power, motor, or engine—and mechanisms are needed to convert and transmit that force from the source to the machine.

### New Creation

The more you try to perfect your skills in something, the more you realize that the basic foundation is the most important. Likewise, when you are trying to design something new, knowing these simple mechanisms will help you to make a machine that is more original, more useful, and easier to use than anything that existed before. It will also help you transmit your creativity from your head to your fingers to draw, cut, and paste, which liberates your mind and leads to new ideas full of creativity.

So how would you like to take a trip back in time to feel the passion of ancient inventors, taking each of the simple machines—lever, crank, cam, gear, and linkage—and putting them together through trial and error, like pieces of a jigsaw puzzle? This book is a good place to start your trip, and it will even take you to the future, to a new world of creation full of dreams and imagination.

**Toshio Arai**
Currently CEO, Concept Plus Co., Ltd.
Previously worked at Sony as a technical engineer for 27 years
Important figure in the development of the Walkman and Discman

# 3

# How to Build Karakuri

! Seven of the ten basic karakuri models included in this book (Cam A, Cam B, Cam C, Cam D, Gear A, Gear B, and Geneva stop) can make a model that's connected with one handle. If you want to build the kits connectedly, please see p.105 before you start.

# Basic Paper Crafting Techniques

One great thing about paper crafting is that you can somehow manage without special tools or skills. But with the right tools and helpful hints, you can make the process much easier and also improve the result. So before you start, let's gather the needed tools and learn some tips. Keep in mind when you're working—don't rush and don't hurt yourself! Take it easy and have fun working at your own comfortable pace.

## Useful tools:

### Craft knife
A craft knife works best when you want to make a clean cut. Choose one that is small and easy for you to hold, and use it until you feel comfortable with it. X-ACTO knives are also very good for making accurate cuts.

### Blades for craft knife
Be generous and change the blade often when it gets dull after some use. Dull blades will not only give you unclean edges on the cut paper but they can also cause the knife to slip and cut your finger! When you're done using a blade, be sure to keep it in a small bottle or a container for proper disposal.

### Cutting mat
It's important to place this mat under the paper when you cut it with a craft knife. It will keep your table from being damaged and also give a clean cut edge.

### Scissors
Scissors come in handy when you want to separate parts before cutting them out more precisely with a craft knife. You may also want to use scissors to cut curves and small parts before you've gotten accustomed to using the knife.

### Ruler
Always use a ruler when you cut the model with a craft knife or when you score the folding line. If you haven't gotten used to the craft knife, aluminum or steel rulers are better to use than plastic or wood, because you might accidentally cut into and damage them. Triangular rulers also come in handy.

### White PVA-type craft glue
Water-based wood glue or white Elmer's craft glue are well suited for paper crafts. Glue should turn clear when it dries. Glue sticks don't work well for paper crafts.

### Stylus with rounded point
By scoring a light groove along the folding line of a paper model, you can make a clean fold. You can get something called a "bone folder" in craft or art supply stores. If you can't find a bone folder, you can use a ballpoint pen that's out of ink or any stylus with a pointed tip, but don't use anything too sharp—it will damage the model part you're folding or even rip right through it. When you score the lines, be sure to do it on a cutting mat or some thick paper.

### Compass-type circle cutter
This compasslike instrument with a blade is used to cut out a perfect circle of any radius. Don't try to cut out a circle in just one stroke—cut out the circle with a few short strokes, turning the compass slowly around the fixed center point.

### Double-sided tape
When attaching two large surfaces, using craft glue may not be a good idea, because the moisture of the glue will buckle the paper. In such a case, you can instead use double-sided tape. But be careful—once the tape is attached, you can't move its position.

### Tweezers
Tweezers are used to build very small parts or inner parts into which your fingers cannot reach. It's a good idea to have two different kinds of tweezers, one with a pointed tip and another with a flat tip.

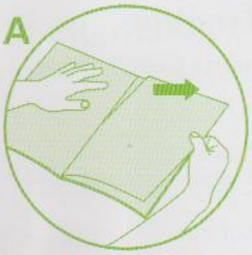
### Toothpicks
Toothpicks are used as "brushes" to apply glue to paper surfaces. They can get clotted with glue after a few uses, so it's a good idea to have a few spares.

# Tips as you work:

## Cutting

Gently pull off the model page from the spine of the book (A). After roughly separating the parts with scissors, cut them out carefully with a craft knife, using a ruler for straight edges (B). For circular parts it's best to use a circle cutter (C); if you don't have one, try placing the knife in one spot and rotating the paper. If you're cutting out a few different parts at once, use a pencil to write the number on the back to avoid a mix-up.

A



Be careful not to tear the paper. If it doesn't come off the spine, use a craft knife to cut it.

B

Cover the part you want to cut out with the ruler, to avoid cutting into the part accidentally.

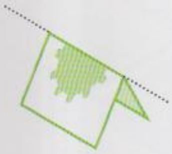
C

Test the circle cutter on the margin of the page until you feel comfortable using it.

## Folding

To make a hill fold, fold so that the front side of the paper is facing out. With a valley fold, the front side should be facing in (A). Use a ruler and a stylus or bone folder to score the folding line (B). Score gently over a few times so as not to damage the paper. All folding lines should be scored and folded before the parts are attached. For the best results, mark the ends of the folding line with a stylus, flip the part, and score the folding line from the back, so that the front surface of the fold remains perfectly clean (C).

A



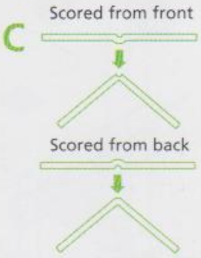
Hill fold

Valley fold

B

With small parts, it is better to score before you cut them out.

C

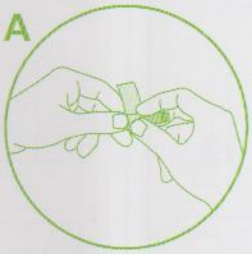



Scored on the backside of the paper, the front surface stays neat and perfect.

## Assembling

Before you start gluing the parts, try assembling them without glue, to think about the order in which they should be attached. Parts with curves should be curled first before being glued (A). Don't apply glue directly from the bottle; pour some out on scrap paper and apply evenly using a toothpick (B). After you attach the parts, wait for the glue to dry completely (C). Wash your hands often so they don't get too sticky!

A



Wrap the part around something like a pen to make it curl.

B

Don't put glue on too many parts at once—they'll begin to dry before you attach them!

C

Use tweezers to attach small parts. When making a square rod, you can flatten the part before applying glue.

### Coloring

Try making your original karakuri using coloring tools such as markers, watercolor paint, and colored pencils. Do be careful using watercolors—if you paint a large surface, the moisture may cause it to buckle. To color a large surface, it's better to paint a separate paper to cut and attach to the model using double-sided tape or spray glue. If you are used to making paper models, you may paint the model parts before cutting them out, let them dry flat, cut them out, and then start building.

### Making it your own

You can customize your paper-craft model by changing the shape of a cam or the length of a rod, or attaching other pieces of your design. You can use tracing paper to trace the parts and transfer them onto thick paper to make your original parts, or you can use the computer to design and print out the parts. There is software for most computers that lets you draw shapes easily, so you may want to try using that if you have a computer at home.

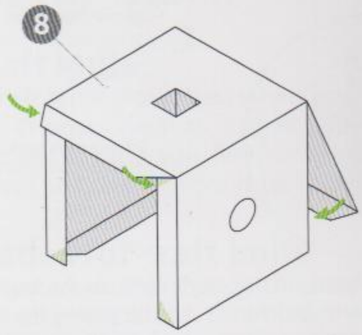
# Cam A

## The rod makes a repetitious vertical motion.

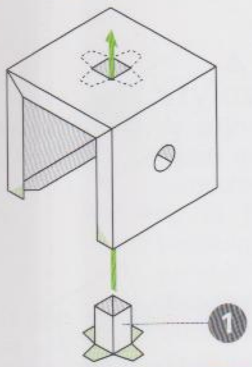
MODEL ▶ p.65–67 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.22

| | |
|---|---|
| Solid line | Cut |
| Dotted line | Score + hill fold |
| Dash line | Score + valley fold |
| | Glue (indicated in green below) |
| | Cut out |
| + | Center point of circle (if using a circle cutter) |

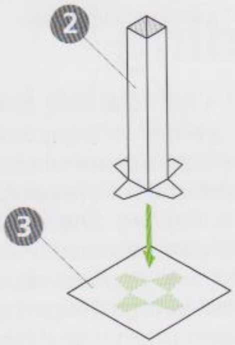
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.



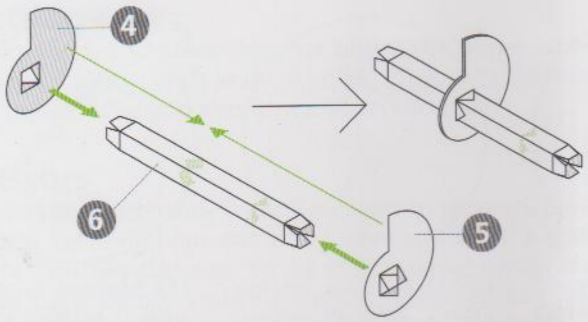

**B** Insert **1** through the top hole and glue from the inside.



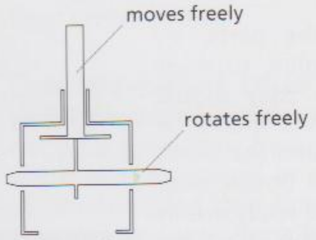

**C** Glue **2** to **3**.



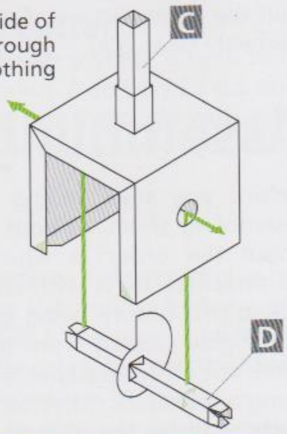

**D** From each end of the axle, slide on the two cams and glue them to each other and to the axle, making sure that the edges are aligned.



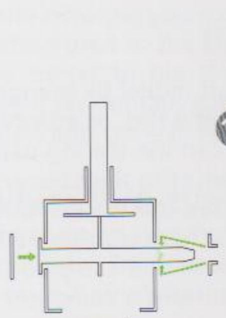

**E** After inserting **C** from the inside of the display stand, place **D** through the side holes. In this step, nothing is glued.

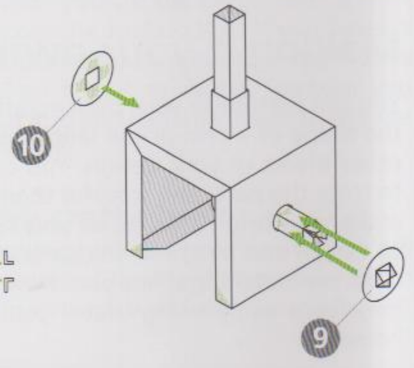


cross section

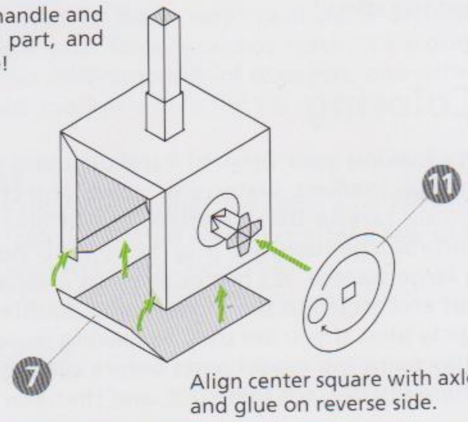



**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.


cross section




**G** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

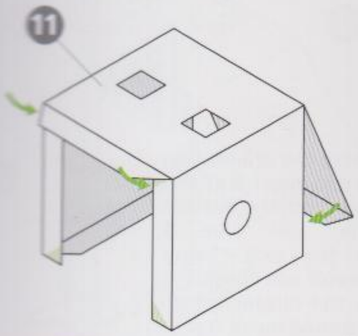
# Cam B

## Two rods make a vertical movement alternately.

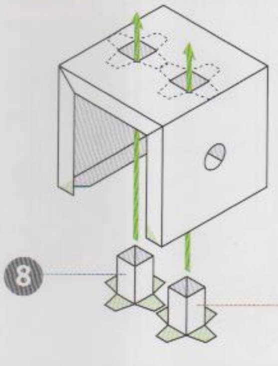
MODEL ▶ p.69–71 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.22

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue | (indicated in green below) |
| Dotted line | Score + hill fold | | Cut out |
| Dash line | Score + valley fold | + | Center point of a circle (if using a circle cutter) |

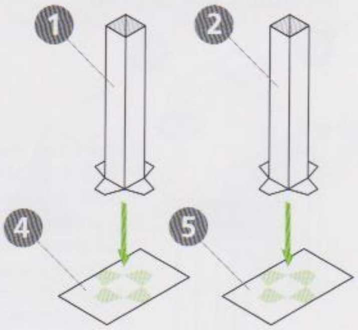
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.



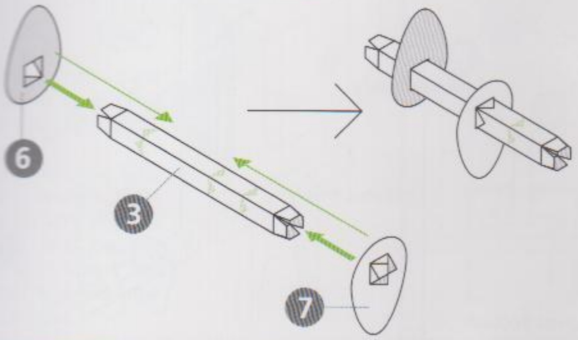

**B** Insert **8** & **9** through the top holes and glue from the inside.



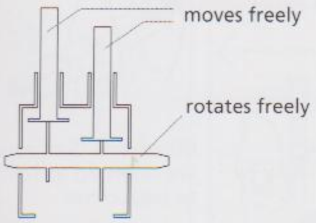

**C** Glue **1** to **4**, and glue **2** to **5**.



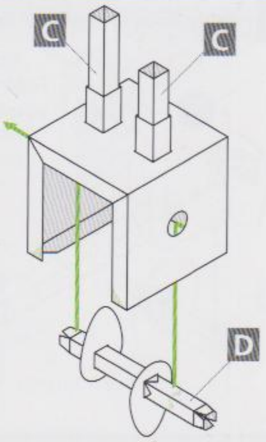

**D** From each end of the axle, slide on the two cams and glue them to the axle on the marks, making sure the cams are oriented at 180° to each other.



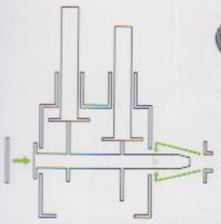

**E** After inserting **C** from the inside of the display stand, place **D** through the side holes. In this step, nothing is glued.

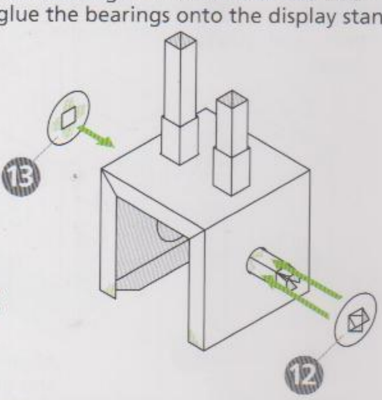


cross section

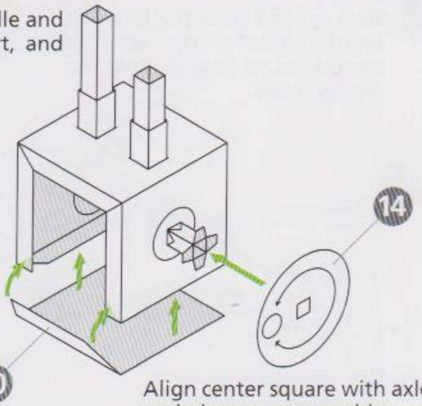



**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.


cross section




**G** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

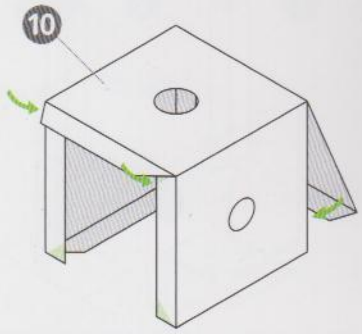
# Cam C

## The rod makes a repetitious horizontal movement.

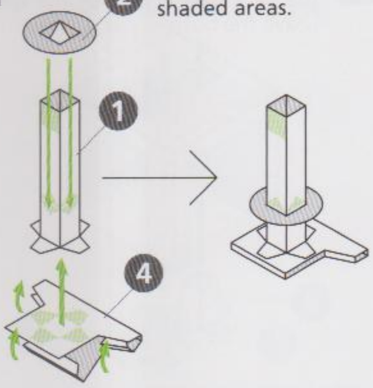
MODEL ▶ p.73–75 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.22

| | | | |
|---|---|---|---|
| Solid line | Cut | | Glue (indicated in green below) |
| Dotted line | Score + hill fold | | Cut out |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

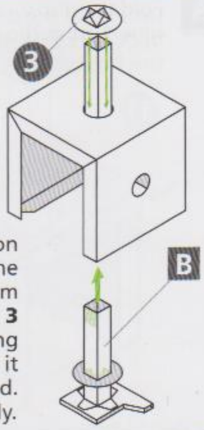
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.




**B** Glue the parts to the shaded areas.



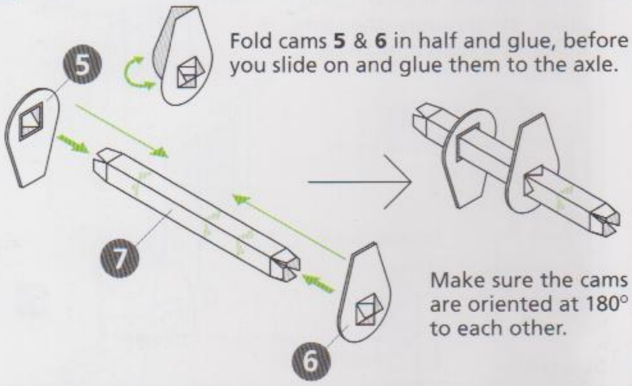

**C** Check the orientation as you insert **B** all the way from the bottom side, and glue **3** to the axle, being careful not to glue it to the display stand. **B** should move freely.



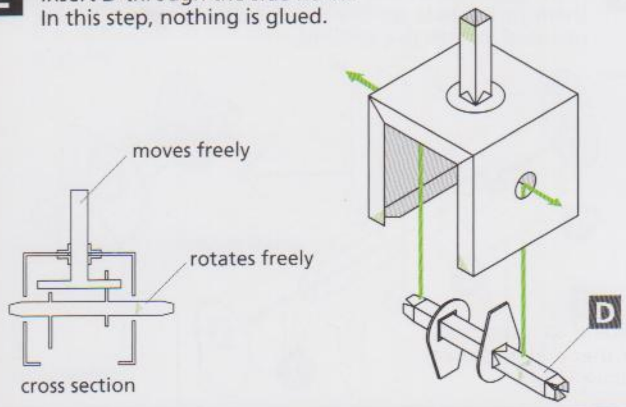

**D** From each end of the axle, slide on and glue the two cams.

Fold cams **5** & **6** in half and glue, before you slide on and glue them to the axle.

Make sure the cams are oriented at 180° to each other.

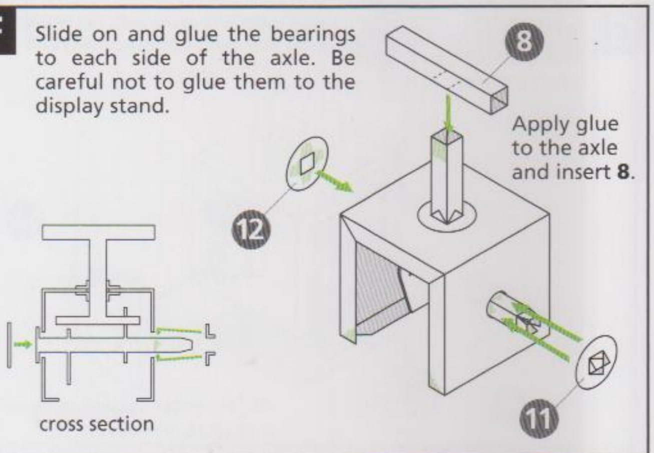



**E** Insert **D** through the side holes. In this step, nothing is glued.

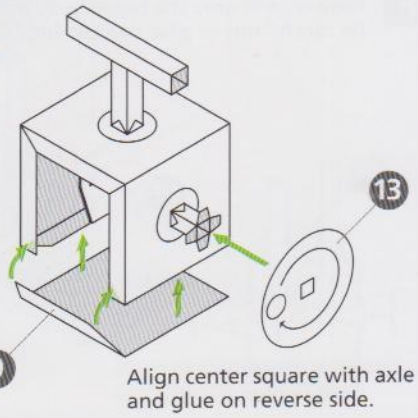



**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue them to the display stand.

Apply glue to the axle and insert **8**.




**G** Attach the handle and the bottom part, and you're done!



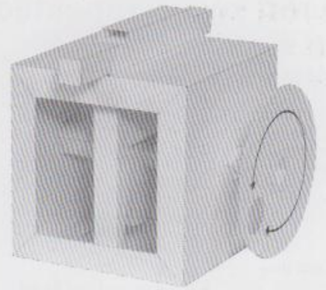

Align center square with axle and glue on reverse side.

# Cam D

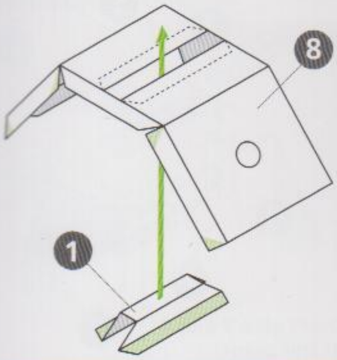
## The rod slides repeatedly in a linear motion.

MODEL ▶ p.77–79 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.22

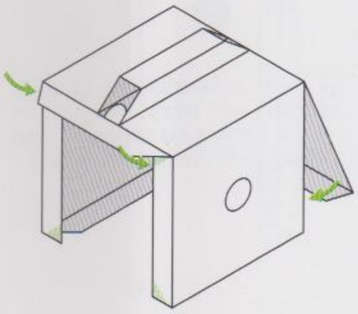
| | | | |
|---|---|---|---|
| Solid line | Cut | Glue | (indicated in green below) |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of a circle (if using a circle cutter) |



**A** Fold the display stand, and insert and glue **1** from the bottom side.

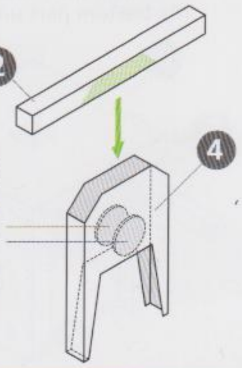



**B** Now build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.



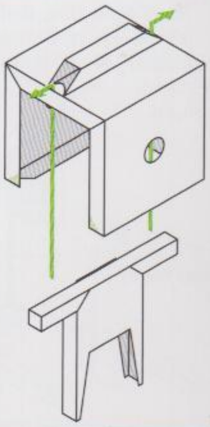
**C** Build **2** and insert into **4**. Glue to both sides of **4**.

Tape two nickels onto each side of **4** on the INSIDE as weight, so that parts can move smoothly when the model is complete.

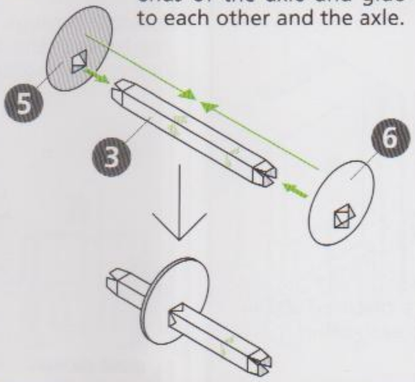



**D** Place the part built in step C in the display stand.

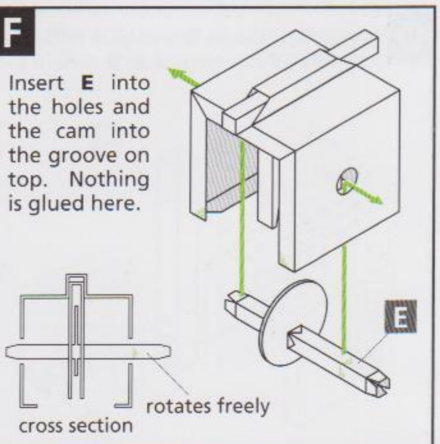
Slide the rod into the front hole first, then slightly bend the display stand to insert the other end into the back hole.



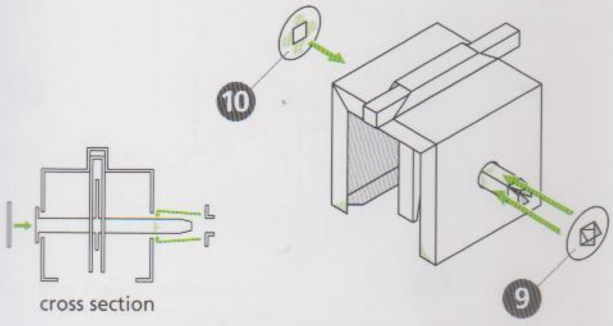
**E** Slide cams through both ends of the axle and glue to each other and the axle.



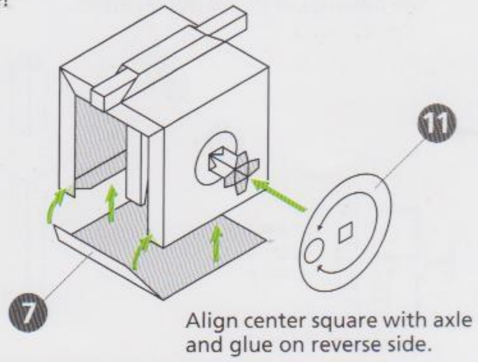

**F** Insert **E** into the holes and the cam into the groove on top. Nothing is glued here.




**G** Slide on and glue the bearings to each side of the axle so that the axle does not slide sideways. Be careful not to glue the bearings onto the display stand.




**H** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

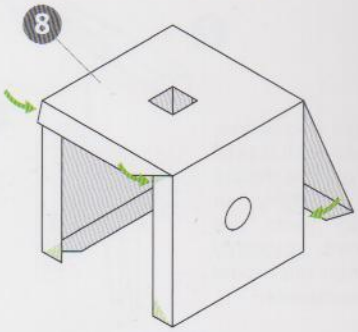
# Crank A

## The rod sways repeatedly in a circular motion.

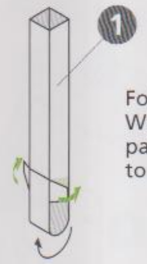
MODEL ▶ p.81–83
EXPLANATION ▶ p.24

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue (indicated in green below) | |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.

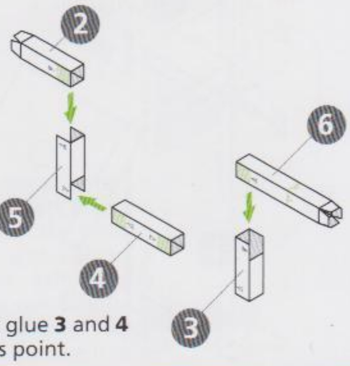



**B**



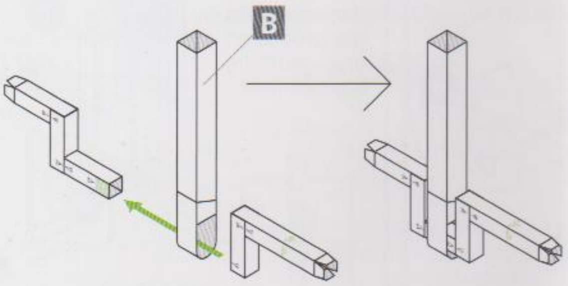

Fold and glue **1**. Wrap the bottom part around a pen to curl, then glue.

**C** Assemble the crank parts so that the arrows match.

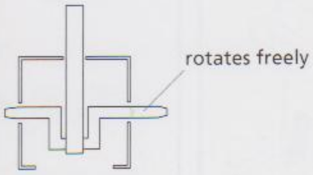



Don't glue **3** and **4** at this point.

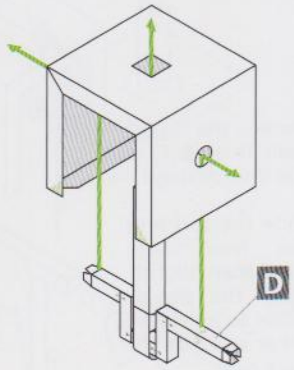
**D** Insert **4** through **B** and glue to **3**. This completes the crank. Be careful not to glue **B**. **B** should move freely.



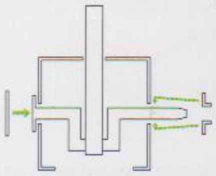

**E** Insert **D** through the side and top holes of the display stand. In this step, nothing is glued.



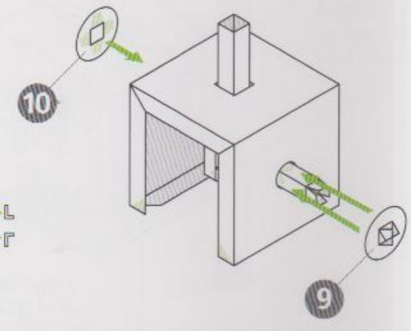

cross section



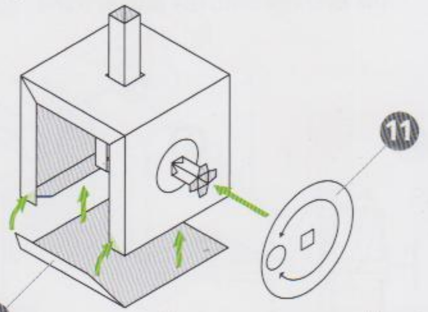

**F** Slide on and glue the bearings to each side of the axle so that the axle does not slide sideways. Be careful not to glue the bearings onto the display stand.



cross section




**G** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

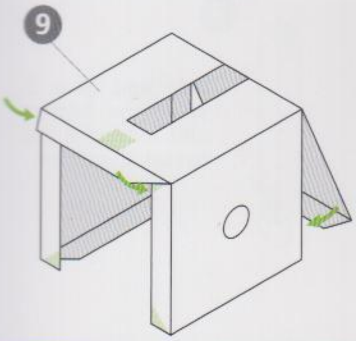
# Crank B (Crank rocker)

## The rod sways back and forth by a linkage mechanism.

MODEL ▶ p.85–87
EXPLANATION ▶ p.24

| | | | |
|---|---|---|---|
| Solid line | Cut | | Glue (indicated in green below) |
| Dotted line | Score + hill fold | | Cut out |
| Dash line | Score + valley fold | + | Center point of a circle (if using a circle cutter) |

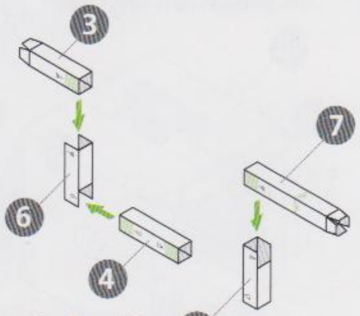
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.




**B**


Fold and glue **1**. Wrap the bottom part around a pen to curl, then glue.

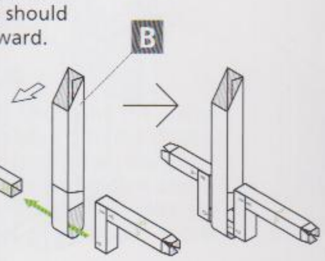
**C** Assemble the crank parts so that the arrows match.



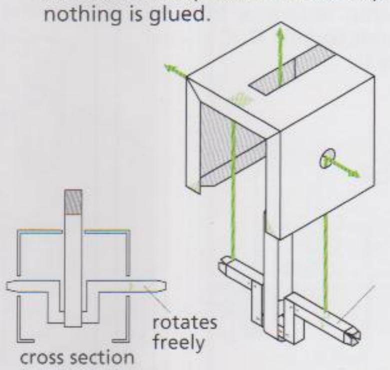

Don't glue **4** and **5** at this point.

**D** Insert **4** through **B** and glue to **5**, noting the orientation of **B**. Be careful not to glue **B**. **B** should move freely.

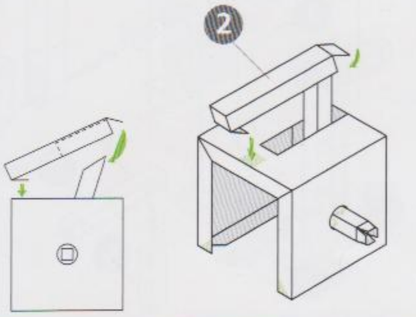
The diagonal opening should face forward.



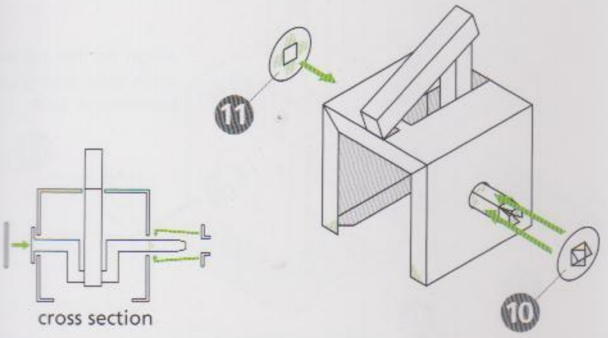

**E** Place **D** in the display stand through the side and top holes. In this step, nothing is glued.



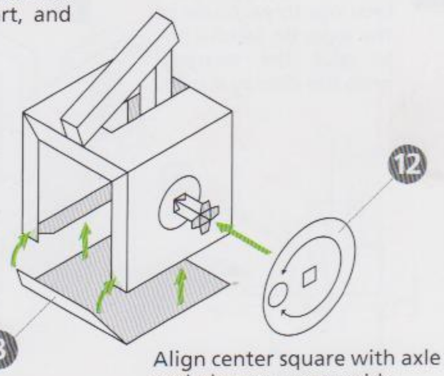

**F** Place **2** on top of the rod and glue. Glue the front end to the display stand.




**G** Slide on and glue the bearings to each side of the axle so that the axle does not slide sideways. Be careful not to glue the bearings onto the display stand.




**H** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

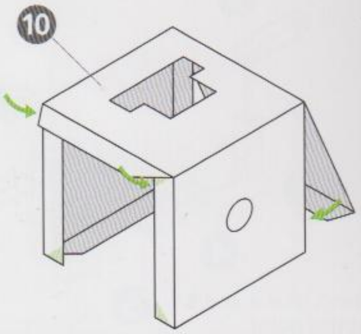
# Crank C (Slider-crank)

## The turning of a crank is converted into a vertical motion.

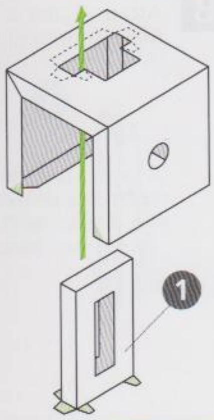
MODEL ▶ p.89–91
EXPLANATION ▶ p.24

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue (indicated in green below) | |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.

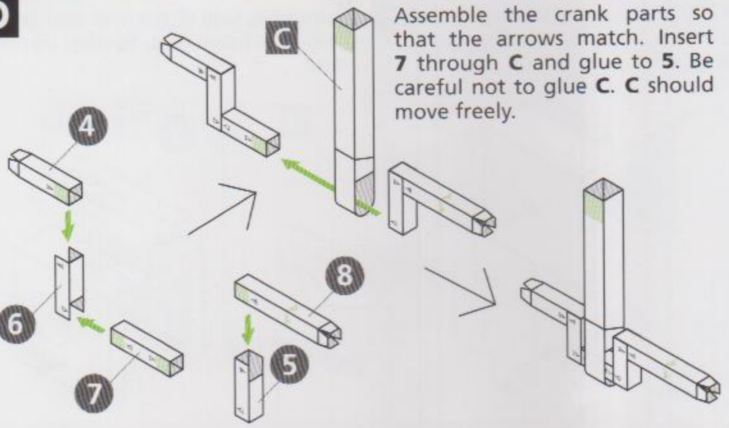



**B** Assemble **1** and insert it through the top hole. Glue from the inside.

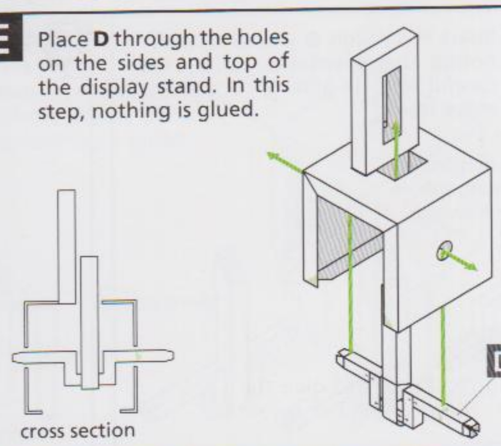



**C** Fold and glue **3**. Wrap the bottom part around a pen to curl, then glue.


**D** Assemble the crank parts so that the arrows match. Insert **7** through **C** and glue to **5**. Be careful not to glue **C**. **C** should move freely.

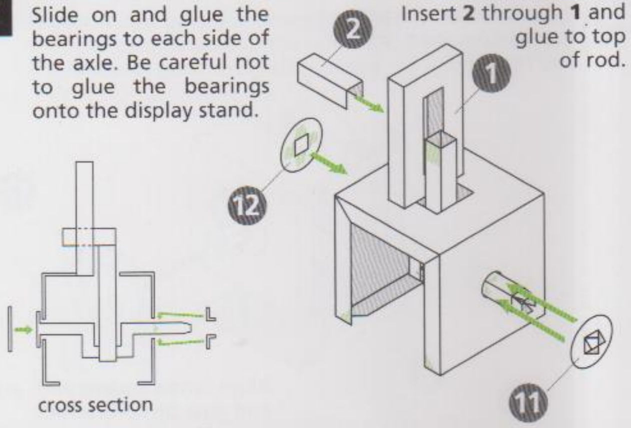



**E** Place **D** through the holes on the sides and top of the display stand. In this step, nothing is glued.



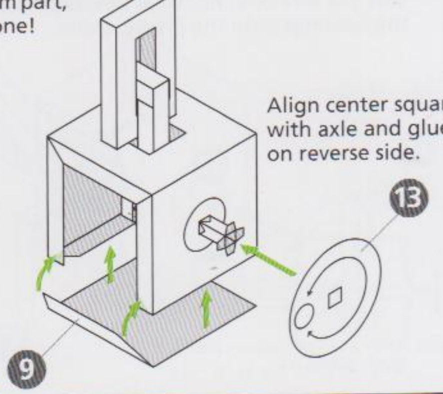

**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.

Insert **2** through **1** and glue to top of rod.




**G** Attach the handle and the bottom part, and you're done!

Align center square with axle and glue on reverse side.



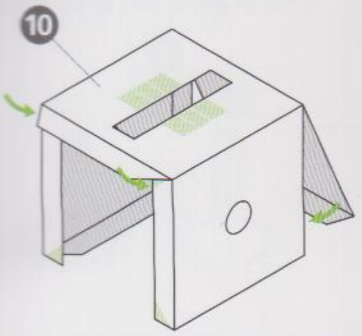
# Gear A

## The gear turns horizontally to the handle.

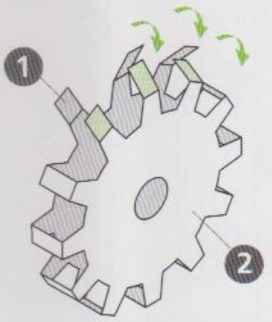
MODEL ▶ p.93–95 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.26

| | |
|---|---|
| Solid line ——— Cut | Glue (indicated in green below) |
| Dotted line ········· Score + hill fold | Cut out |
| Dash line – – – – Score + valley fold | + Center point of a circle (if using a circle cutter) |

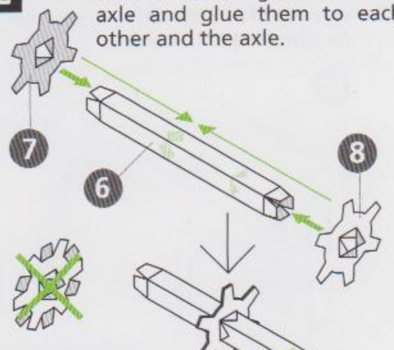
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.




**B** Attach **1** and **2** to make the gear. Make sure to glue each tooth.

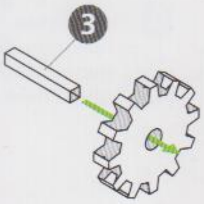


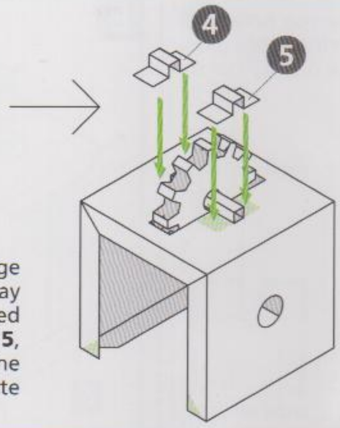

**C** Slide the small gears into the axle and glue them to each other and the axle.




Be sure to match up each tooth.

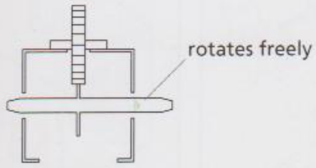
**D**



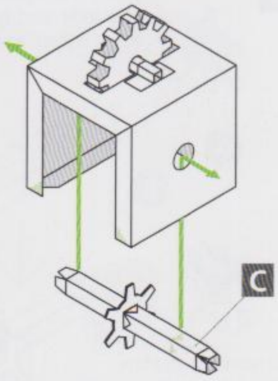




Insert **3** through the large gear, and glue **3** to the display stand. To strengthen the glued areas, cover and glue **4** and **5**, being careful not to glue the gear. The gear should rotate freely.

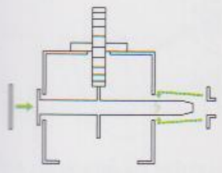
**E** Place **C** through the side holes, making sure that the center gears mesh properly. Nothing is glued in this step.



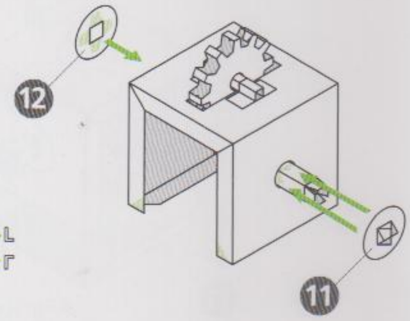

cross section



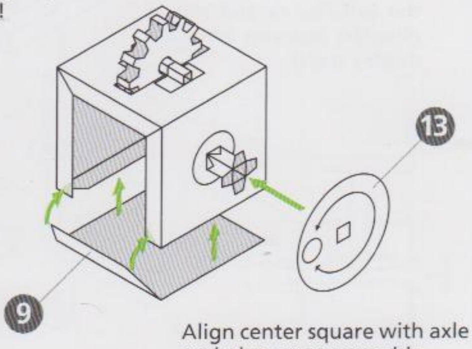

**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.



cross section




**G** Glue the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

# Gear B

## The gear turns perpendicularly to the handle.

MODEL ▶ p.97–99 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.26

Solid line — Cut

Dotted line — Score + hill fold

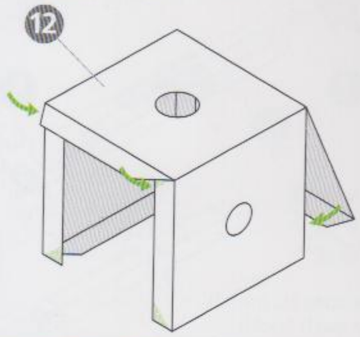
Dash line — Score + valley fold

Glue (indicated in green below)

Cut out

+ Center point of circle (if using a circle cutter)

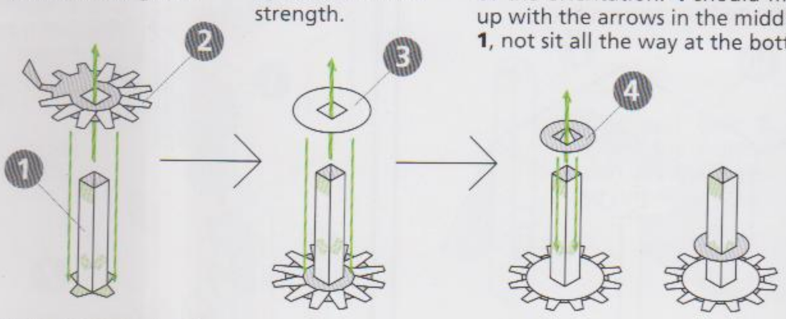
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.




**B** Fold and glue each tooth of the gear...

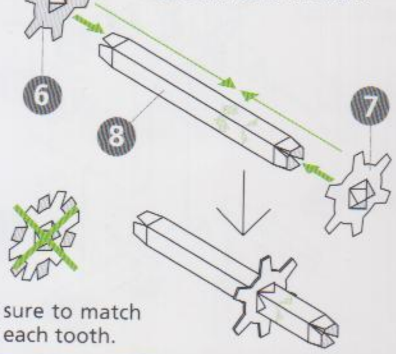
Slide on and glue **3**, to add more strength.

Slide on and glue **4**, being careful of the orientation. **4** should match up with the arrows in the middle of **1**, not sit all the way at the bottom.



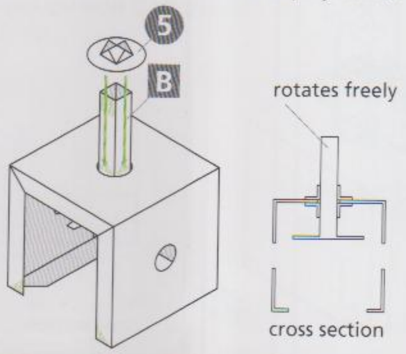

...and insert and glue **1** from the underside.

**C** Slide the small gears onto the axle and glue them to each other and the axle.

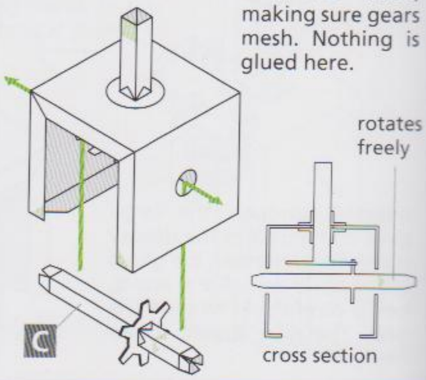



Be sure to match up each tooth.

**D** Insert **B** through the top hole and glue to **5**, being careful not to glue to the display stand.

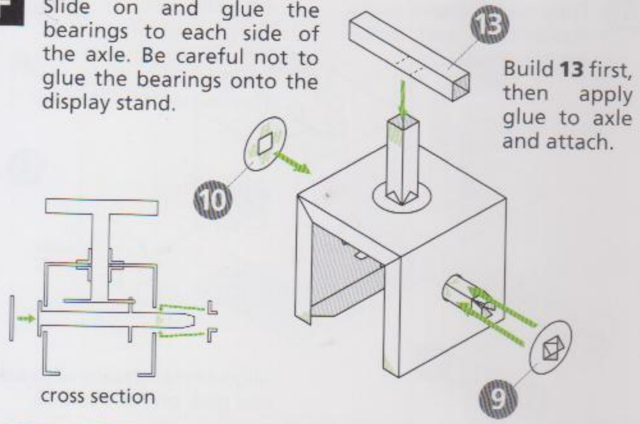



**E** Place **C** through the side holes, making sure gears mesh. Nothing is glued here.

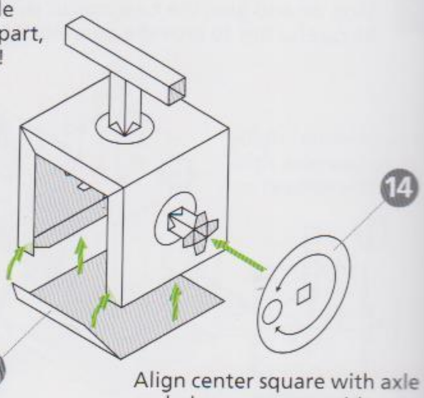



**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.

Build **13** first, then apply glue to axle and attach.




**G** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

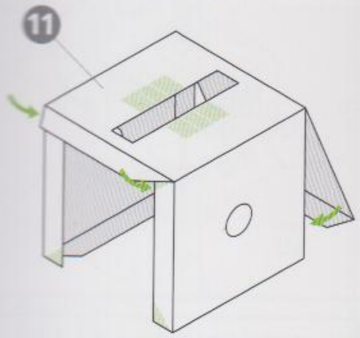
# Geneva Stop

## The wheel turns in a discontinuous rhythm.

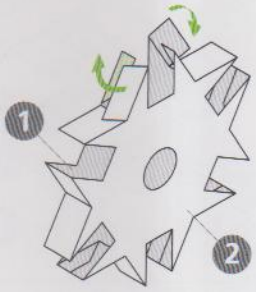
MODEL ▶ p101–103 *Please also use parts on p.105 when making a connected model.
EXPLANATION ▶ p.30

| | | | |
|---|---|---|---|
| Solid line | Cut | | Glue (indicated in green below) |
| Dotted line | Score + hill fold | | Cut out |
| Dash line | Score + valley fold | + | Center point of a circle (if using a circle cutter) |

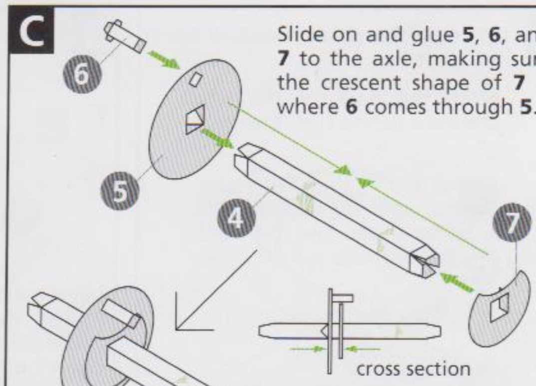
**A** Let's build the display stand. Glue the back part first, then the front. Leave the bottom part unglued.




**B** Attach **1** and **2** to make the gear. Make sure to glue each tooth.

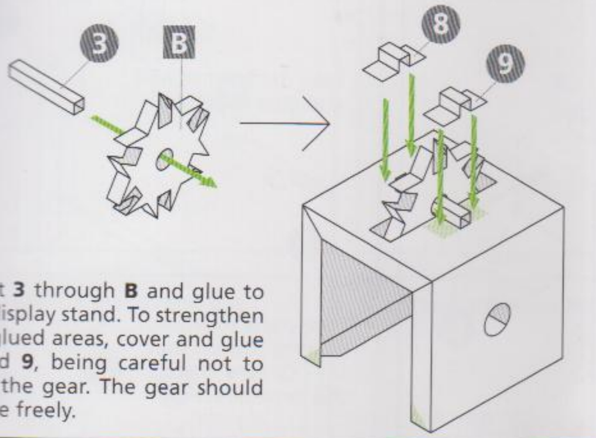



**C** Slide on and glue **5**, **6**, and **7** to the axle, making sure the crescent shape of **7** is where **6** comes through **5**.



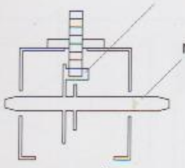

There should be some space between **5** and **7**.

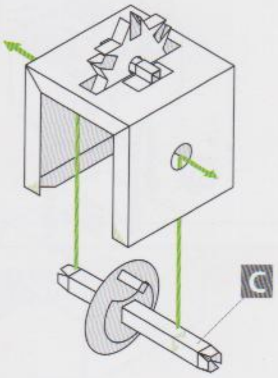
**D**



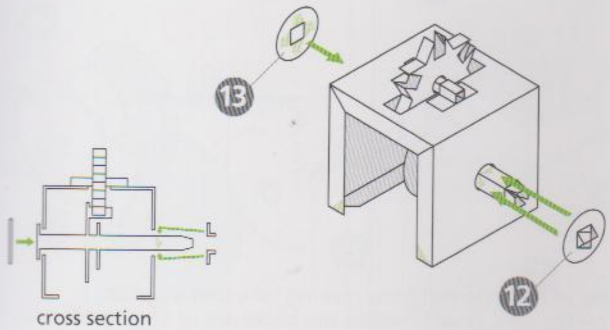

Insert **3** through **B** and glue to the display stand. To strengthen the glued areas, cover and glue **8** and **9**, being careful not to glue the gear. The gear should rotate freely.

**E** Place **C** through the side holes, making sure the pin fits into one of the slots. Nothing is glued in this step.

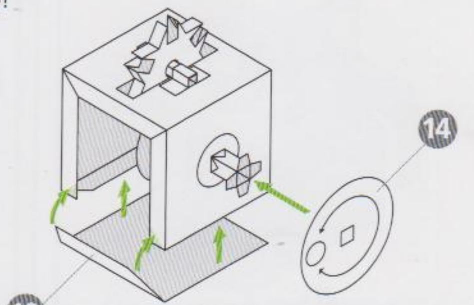



**F** Slide on and glue the bearings to each side of the axle. Be careful not to glue the bearings onto the display stand.




**G** Attach the handle and the bottom part, and you're done!




Align center square with axle and glue on reverse side.

# Tea-Serving Robot

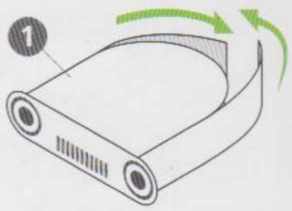
## The robot's head bobs up and down as he moves forward. Will he deliver the teacup without knocking it over?

MODEL ▶ p.113–115

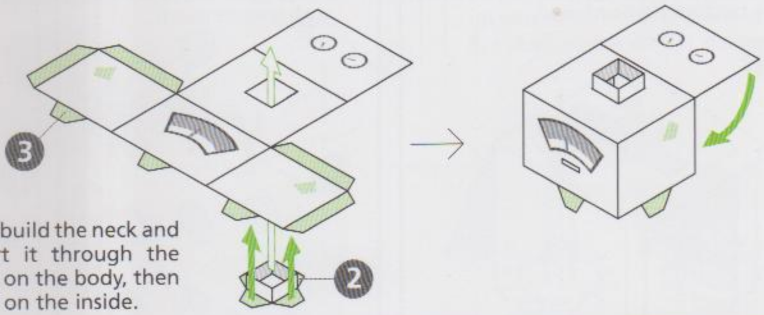
| | | | |
|---|---|---|---|
| Solid line | Cut | (glue pattern) | Glue (indicated in green below) |
| Dotted line | Score + hill fold | (hatched pattern) | Cut out |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

**A** Let's build the robot's head.

Wrap the back of the head around a pen to curl, then glue.

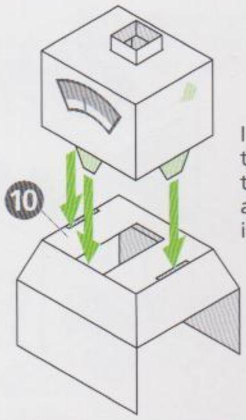



**B** Now build the upper body.



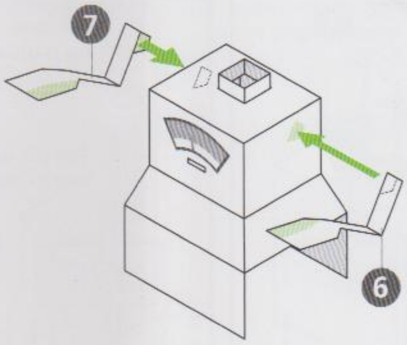

First build the neck and insert it through the hole on the body, then glue on the inside.

**C** Glue together the upper and lower bodies.



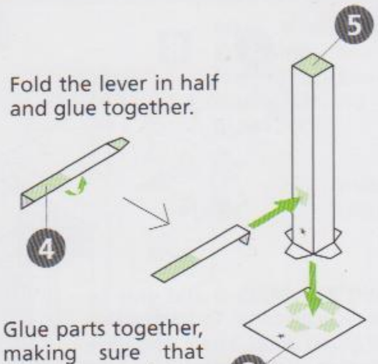

Insert through the slits and glue inside.

**D** Glue on the arms.



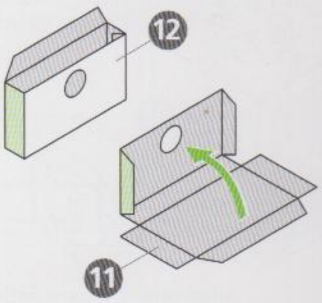

**E** Let's build the lever and rod.

Fold the lever in half and glue together.

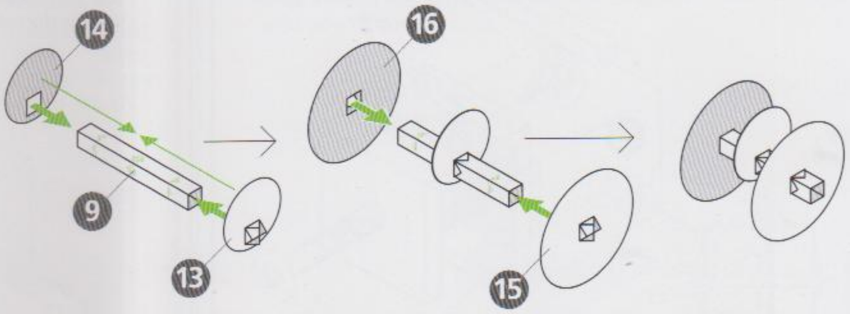



Glue parts together, making sure that the ◇ are facing the same direction.

**F** Let's build the robot's legs.

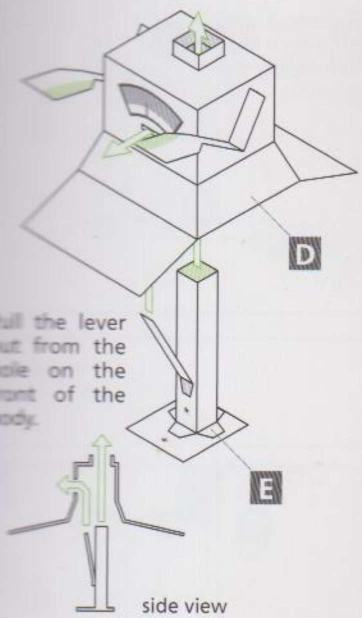



**G** Let's assemble the cams and tires.




Slide on cams from each end of the axle and glue, making sure that they match the appropriate triangles on the axle. Glue together the backsides of **13** and **14**.

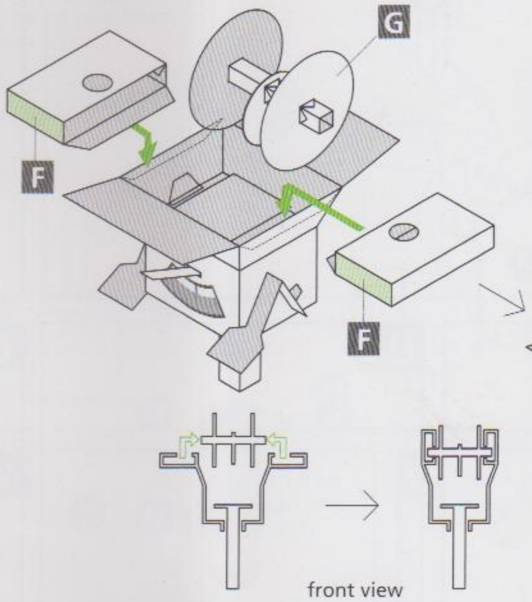
**H** Insert the rod up through the body. Do not glue.




Pull the lever out from the hole on the front of the body.

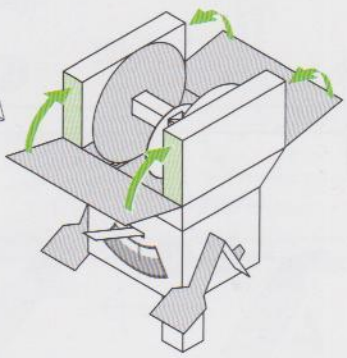
side view

**I** Flip the body upside down and glue the legs on the inside.

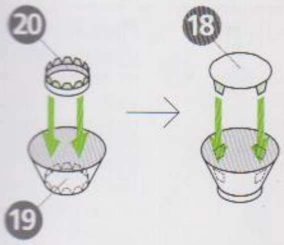



front view

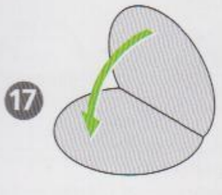
Insert the ends of the rod into the holes on the legs, and glue the front and back sides of the body. Do not glue the rod.



**J** Build the teacup and tray.

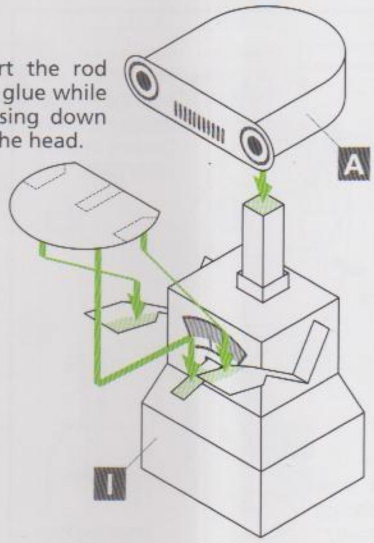



Fold the tray in half and glue.

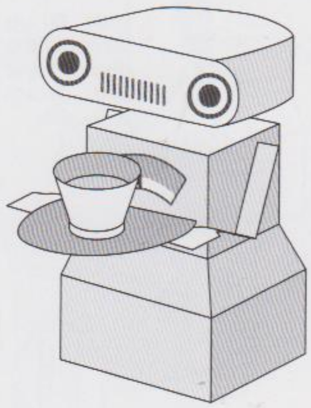



**K** Attach the head and tray.

Insert the rod and glue while pressing down on the head.

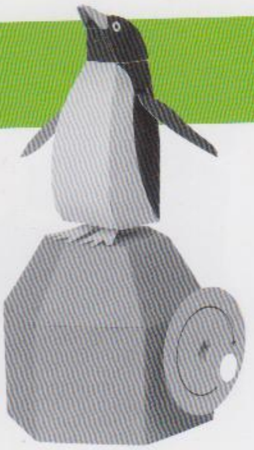



**L** Place the cup on the tray, and you're done!



Can you serve the tea without knocking over the cup?

# Ready to Fly



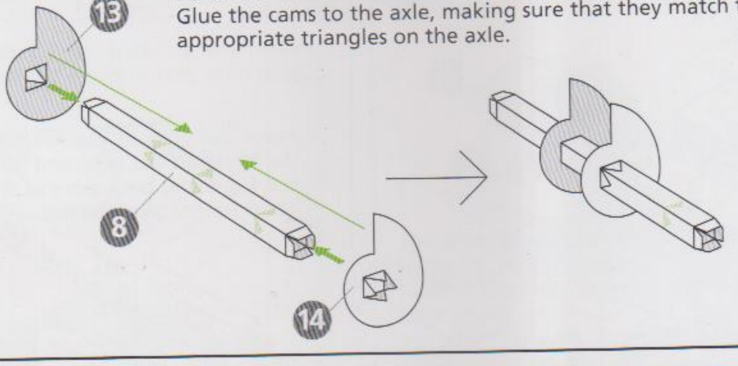
**The persistent penguin keeps flapping his wings, hoping to fly. Who knows, maybe one day he really will take off!**

MODEL ▶ p.117–123

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue (indicated in green below) | |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

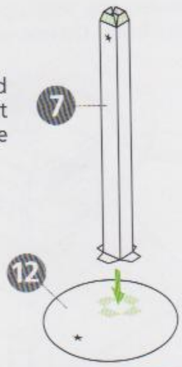
## A

Build the axle and slide on the two cams from each end. Glue the cams to the axle, making sure that they match the appropriate triangles on the axle.

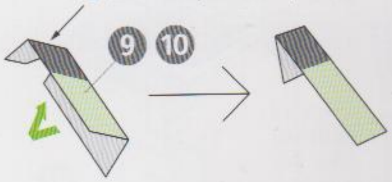



## B

Glue together **7** and **12**, making sure that the ♢ are facing the same direction.

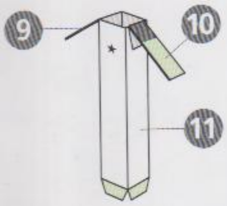



## C



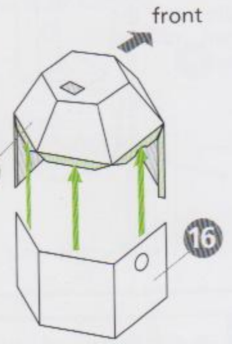

Fold the parts for reinforcement and attach with glue.

## D




Build **11** and attach **9** and **10** with glue.

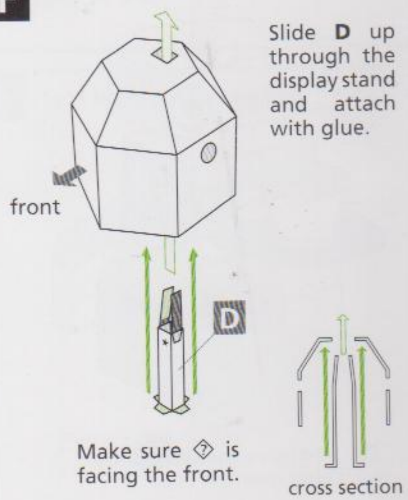
## E




Build the display stand.

## F

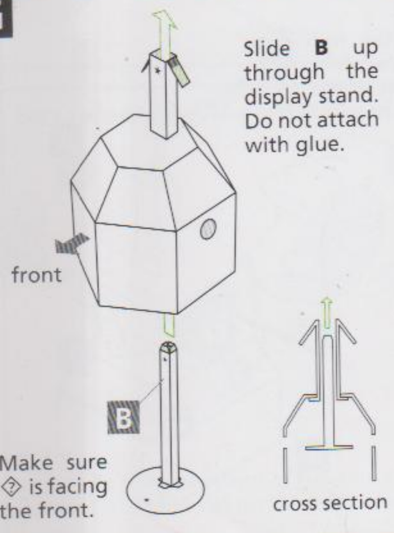
Slide **D** up through the display stand and attach with glue.




Make sure ♢ is facing the front.

## G

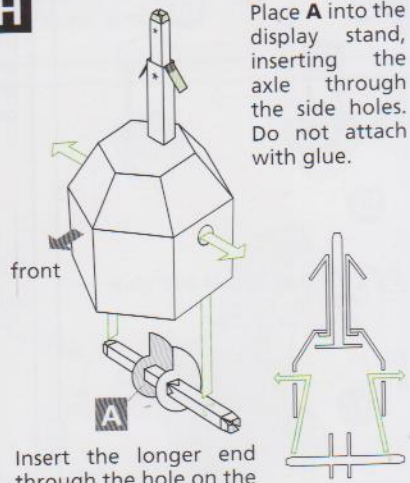
Slide **B** up through the display stand. Do not attach with glue.




Make sure ♢ is facing the front.

## H

Place **A** into the display stand, inserting the axle through the side holes. Do not attach with glue.

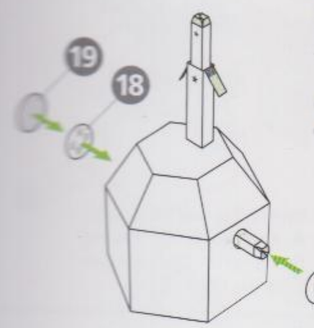


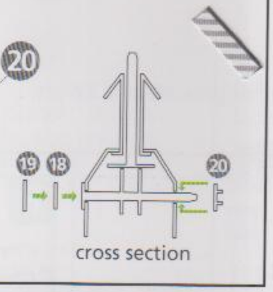

Insert the longer end through the hole on the right, facing front.

**I**

Slide on and glue the bearings to each side of the axle. Be careful not to glue them to the display stand.

Glue **19** to cover the white on the back of **18.**

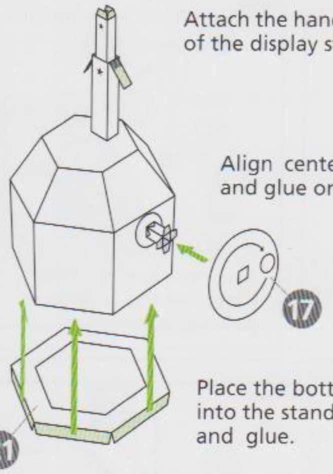


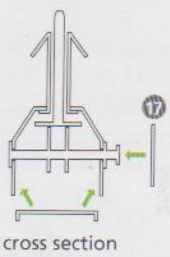

**J**

Attach the handle and the bottom of the display stand.

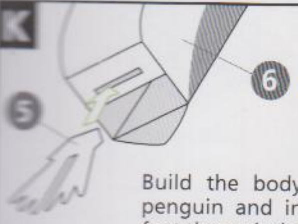
Align center square with axle, and glue on the reverse side.




Place the bottom into the stand and glue.



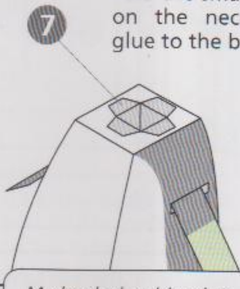

**K**




Build the body of the penguin and insert the feet through the bottom slot. Do not glue.

**M**

Fold the small flaps on the neck and glue to the body.

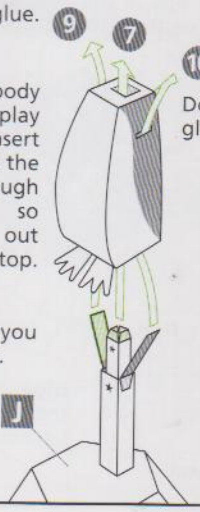



**L**

Do not glue.

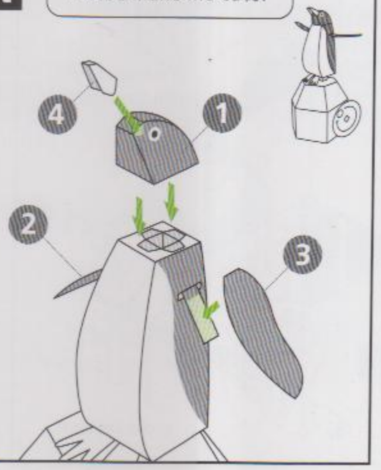
Place the body on the display stand and insert the neck and the arms through the holes so they come out through the top.

It's easy if you use tweezers.



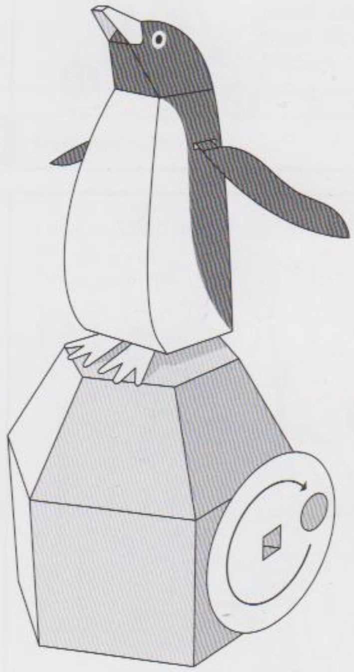

**N**

*My beak should point slightly upward. Please make me cute!*

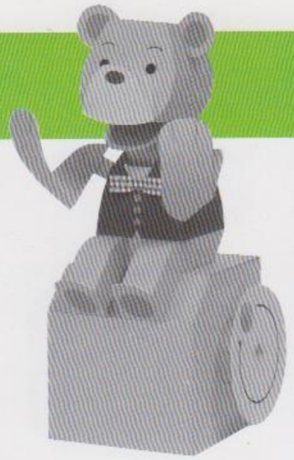



**O**

Now it's done!



# Peek-a-Bear



## A cute bear wants to play peekaboo with you! Have fun pacing the speed as you turn the handle.

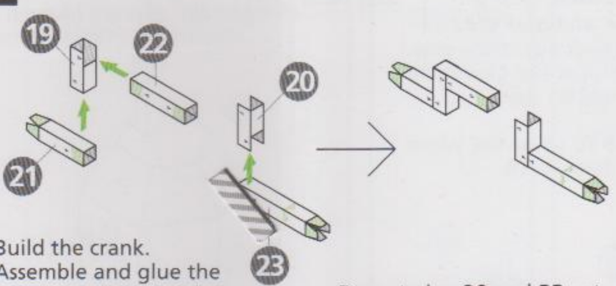
MODEL ▶ p.125–131

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue (indicated in green below) | |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

### A


Wrap the bottom part of **17** around a pen to make it curl.

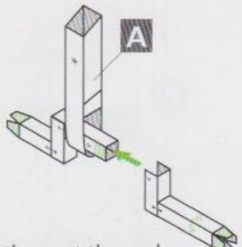
### B




Build the crank. Assemble and glue the parts so the triangles point to each other.

Do not glue **20** and **22** yet.

### C



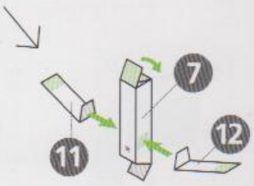

Insert the part through **A** and glue, ⟐ facing front and the longer axle on the right.

### D

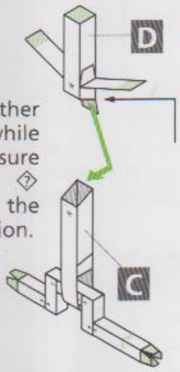
Crease this part firmly.

11 12

Fold these parts and glue to **7**.




### E



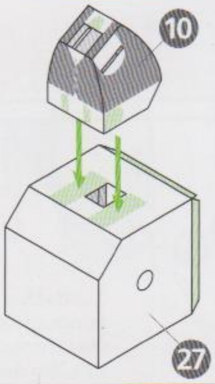

Crease this part firmly.

Glue together **D** and **C** while making sure that the ⟐ are facing the same direction.

### F

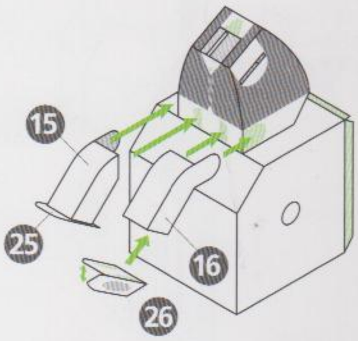
Glue together the body and the display stand.

The bottom of the display stand should remain open.




### G

Glue the legs to the body.

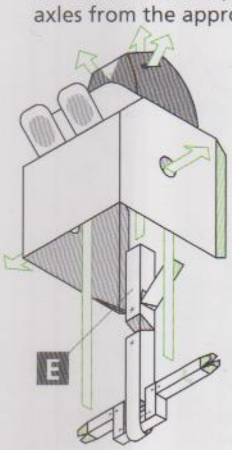


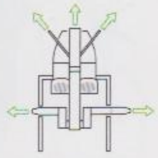

Fold **25** and **26** and glue.

### H

Insert the crank from the bottom, making sure that ⟐ are facing front. Pull out the neck, arms, and the axles from the appropriate holes.

It's easy if you use tweezers.

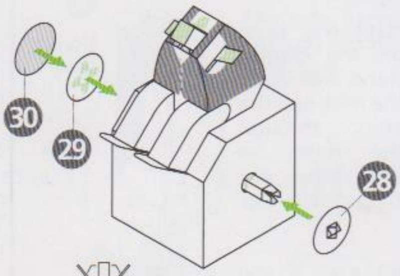


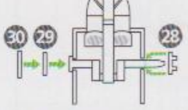



cross section

### I

Slide on and glue the bearings to each side of the axle. Be careful not to glue them to the display stand.

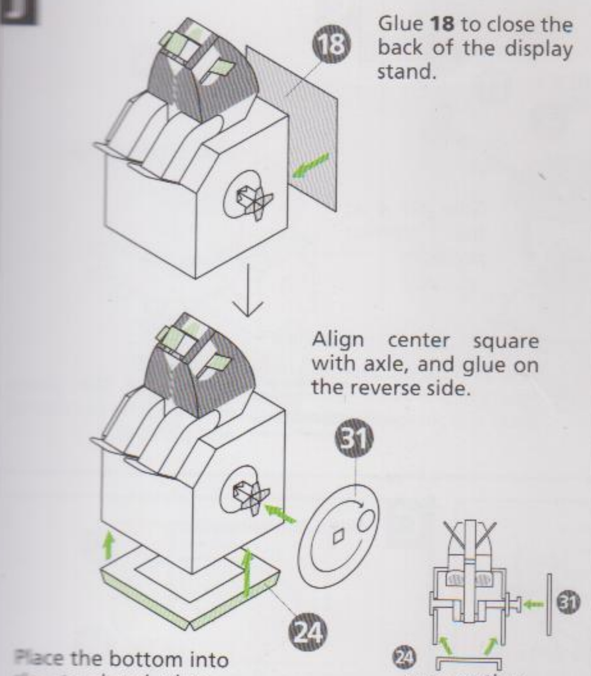



cross section

Glue **30** to cover the white on the back of **29**.

## J



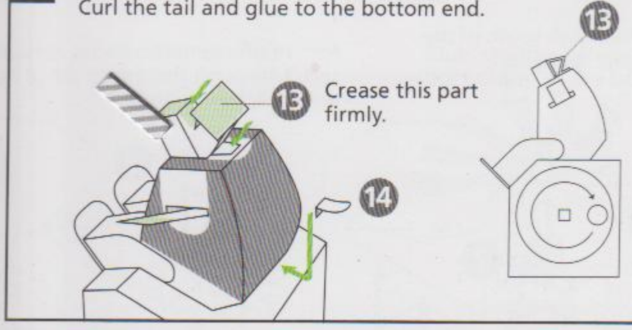

Glue **18** to close the back of the display stand.

Align center square with axle, and glue on the reverse side.

Place the bottom into the stand and glue.

cross section

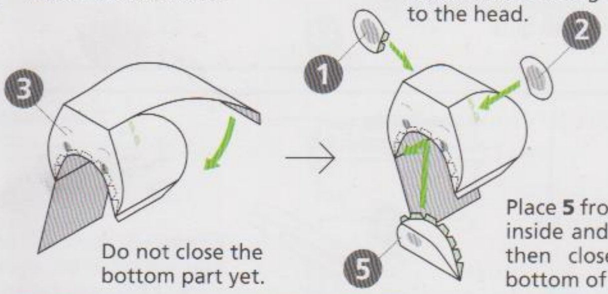
## K




Join the neck and body with **13**.
Curl the tail and glue to the bottom end.

Crease this part firmly.

## L



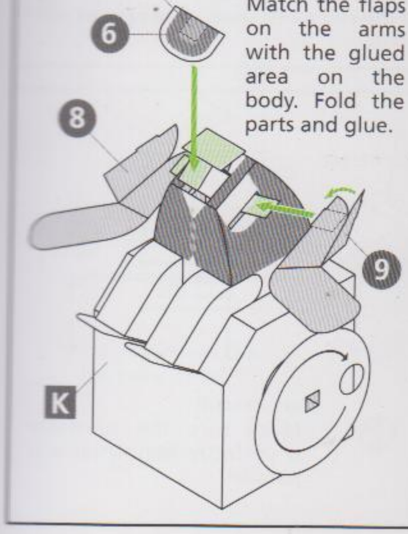

Assemble the head.

Do not close the bottom part yet.

Fold the ears and glue to the head.

Place **5** from the inside and glue, then close the bottom of **3**.

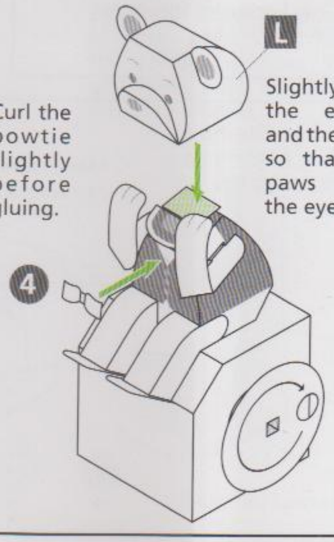
## M




Glue the backside of the tongue.

Match the flaps on the arms with the glued area on the body. Fold the parts and glue.

## N

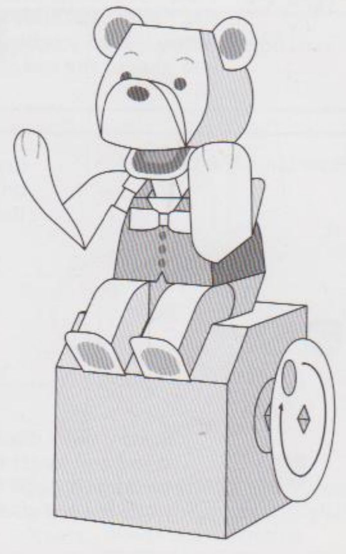



Glue the head. Choose the bowtie you prefer, pink or blue, and glue to the bear's chest.

Curl the bowtie slightly before gluing.

Slightly bend the elbows and the paws so that the paws cover the eyes.

## O



Now you're done!

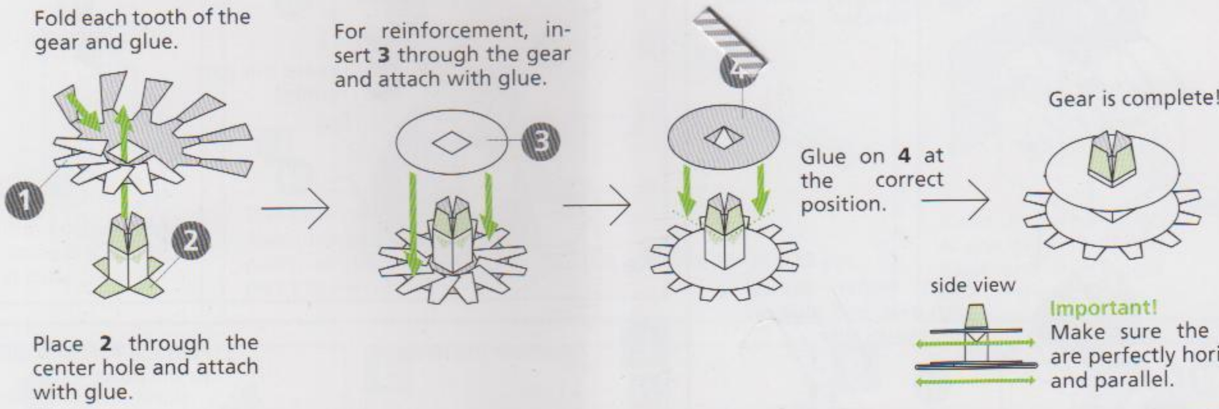
# Wild Wild West

**A steam engine dashes through the wild desert of the West. Watch as it runs in and out of the rocky mountain tunnel!**

MODEL ▶ p.113–143

| | | | |
|---|---|---|---|
| Solid line | Cut | Glue (indicated in green below) | |
| Dotted line | Score + hill fold | Cut out | |
| Dash line | Score + valley fold | + | Center point of circle (if using a circle cutter) |

## A Let's first build the gear.




Fold each tooth of the gear and glue.

Place **2** through the center hole and attach with glue.

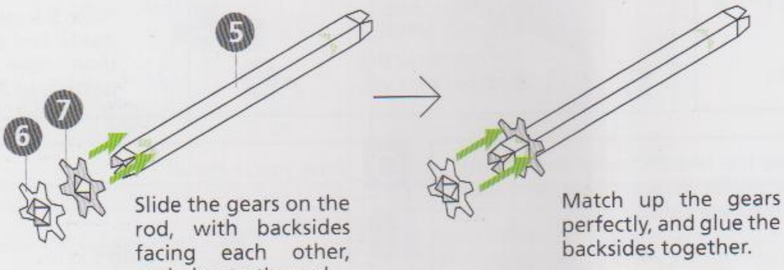
For reinforcement, insert **3** through the gear and attach with glue.

Glue on **4** at the correct position.

Gear is complete!

Important!
Make sure the pieces are perfectly horizontal and parallel.

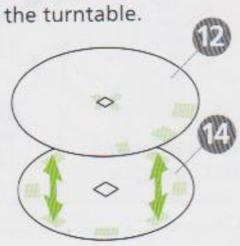
## B Next, let's build the shaft.




Slide the gears on the rod, with backsides facing each other, and glue to the rod.

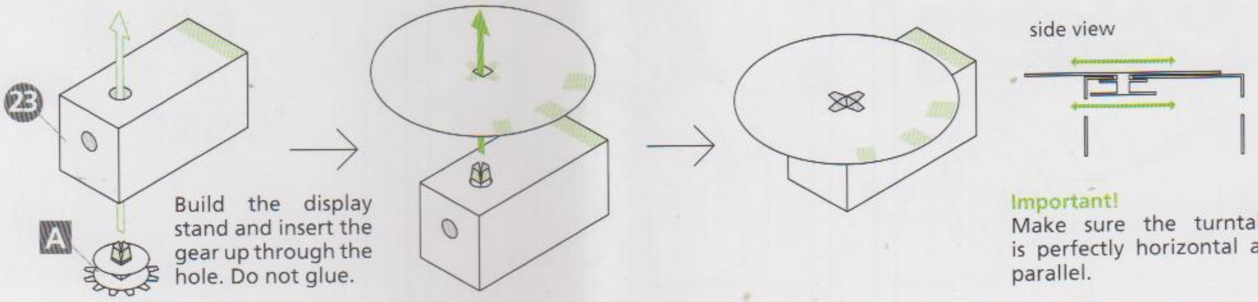
Match up the gears perfectly, and glue the backsides together.

## C Build the turntable.




Glue together parts **12** and **14** for reinforcement, using a small amount of white glue or double-sided tape. Do not use too much glue, or the paper will buckle.

## D Now build the base.



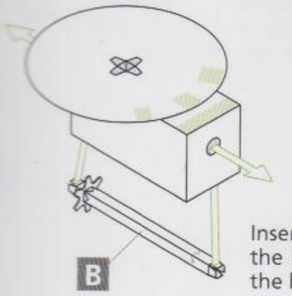

Build the display stand and insert the gear up through the hole. Do not glue.

Insert the gear through the hole on the turntable while holding up the gear from inside, and glue.

Make sure the turntable can turn freely.

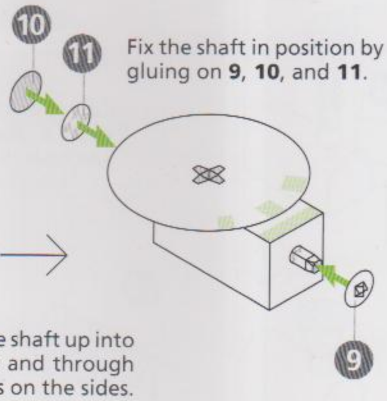
Important!
Make sure the turntable is perfectly horizontal and parallel.

## E

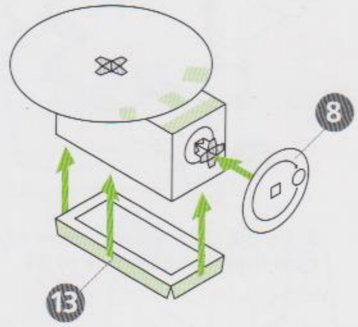



Insert the shaft up into the base and through the holes on the sides.

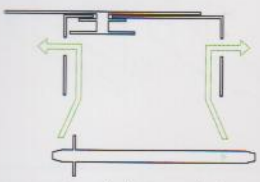
Fix the shaft in position by gluing on **9**, **10**, and **11**.



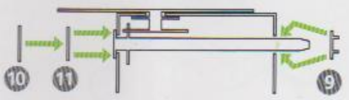

Glue on the handle and the bottom of the base.



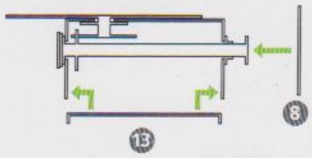

side view



Insert the right end first, and then insert the left end, meshing it with the gear.



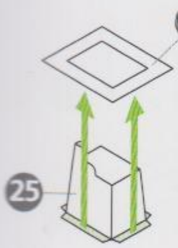

Glue the bearings to the shaft. Be careful not to glue to the base. **10** is for the purpose of covering the backside of **11**.



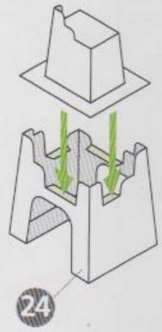

Match up the square center hole with the shaft and attach with glue.

## F

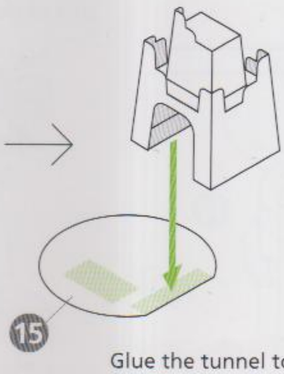
Let's build the tunnel.




Insert **25** from the backside of **26**.



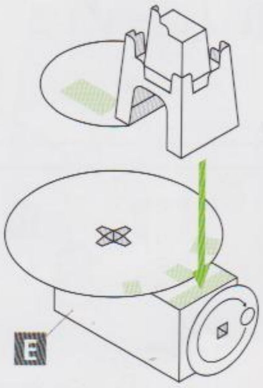

Be careful about the orientation of the parts, matching up the correct symbols. The left and right sides are of slightly different heights.




Glue the tunnel to **15**.

## G

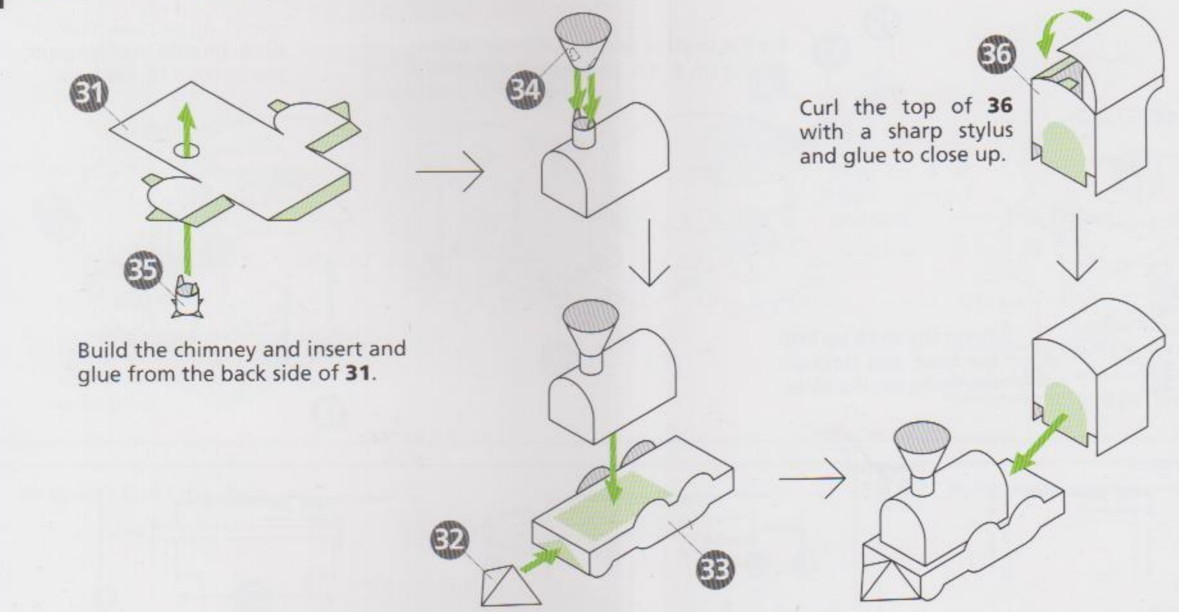
Glue the tunnel onto the base.



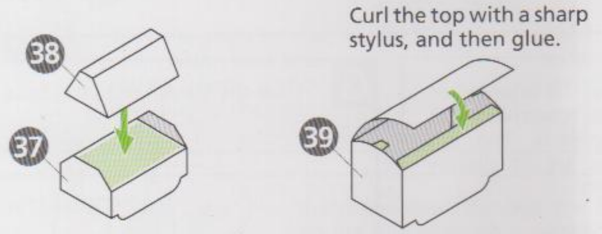

Glue the other side of the tunnel to the base so the circle is slightly elevated above the turntable.

# Wild Wild West (continued)

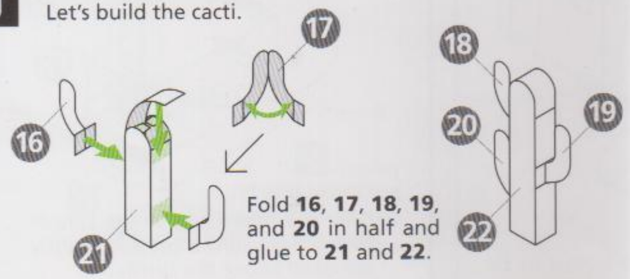
**H** Let's build the steam engine.



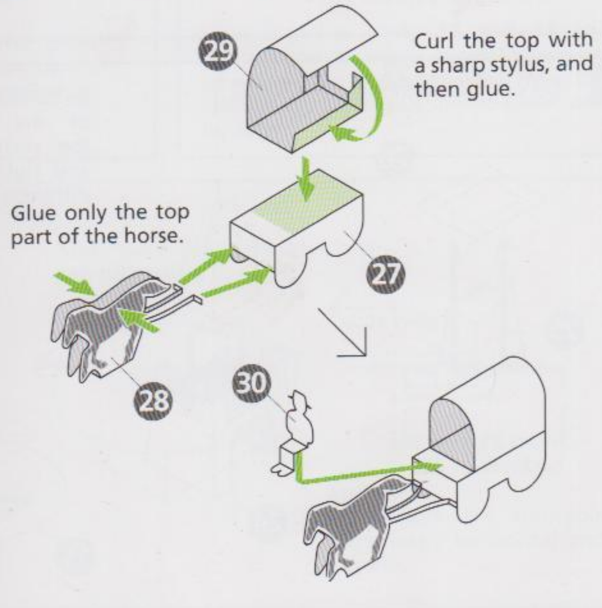

**I** Build the tender and the passenger car.



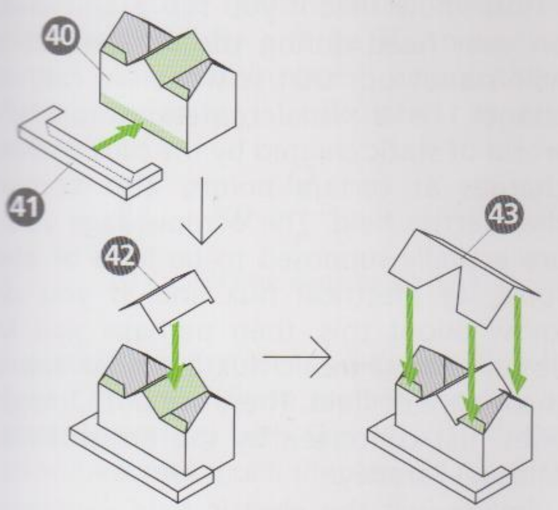

**J** Let's build the cacti.



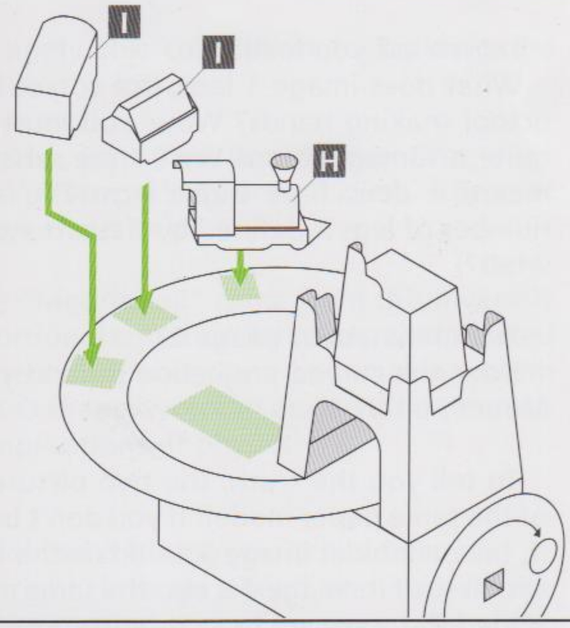

**K** Build the horse carriage.



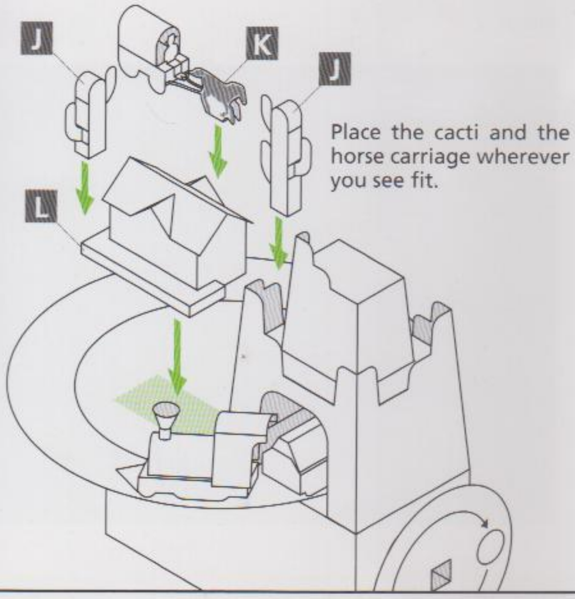
**L** Let's build the station.




**M** Glue the steam engine, tender and passenger car onto the outer edge of the turntable on the railroad tracks.

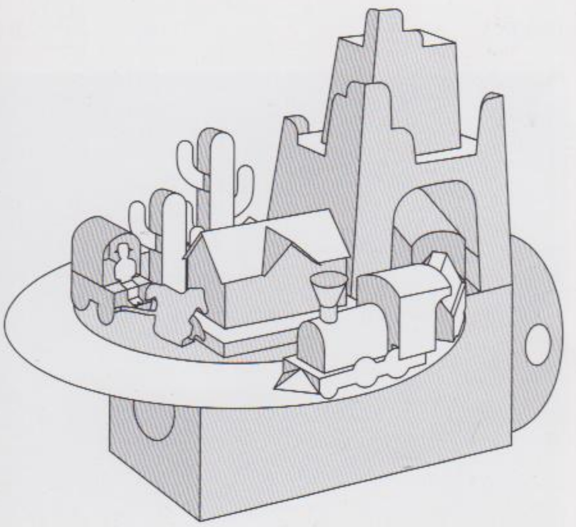



**N** Glue the station, cacti, and horse carriage onto the inner circle **15**.




Place the cacti and the horse carriage wherever you see fit.

**O** And you're finished!



# Models and Physics

## A high school summer spent with karakuri paper models

Let me ask you first:

What does image 1 look like to you? Two octopi shaking hands? Wow, you must have quite an imagination! Well, I see what you mean; it does have eight legs. The actual number of legs is defined by Gauss' Law. (Uh, what?)

Then how about image 2?

Does the curved projection remind you of Mount Fuji?

To tell you the truth, the two pictures are of the same paper model! If you don't believe it, take a look at image 3, which is the bird's-eye view of it. Image 4 is also the same model, folded flat.

You know that if you rub a knit sweater on your head during the dry season, your hair stands up; that is what we call static. Image 1 is a visual representation of the world of static created by the plus and minus charges at certain points, also known as the electric field. The octopus legs you saw are actually supposed to be lines of electric force, or electrical flux line. If you didn't know about this, then perhaps you know about the magnetic flux line that expresses the magnetic field. These are both imaginary lines first conceived by the British inventor Michael Faraday.

Image 2 is the electric field expressed in geographic forms; the point where it rises like a mountain is said to be high in electric

Image 1

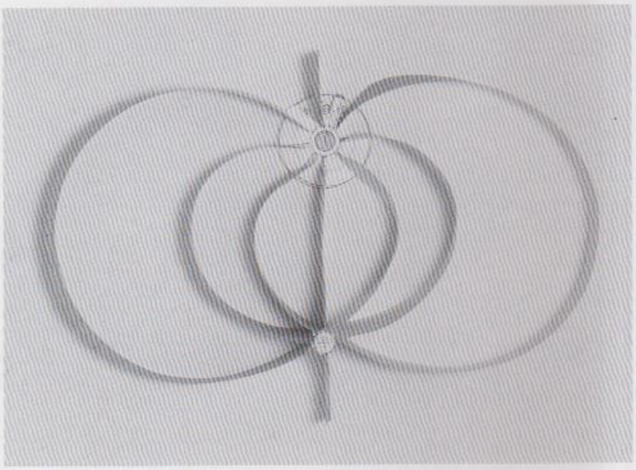
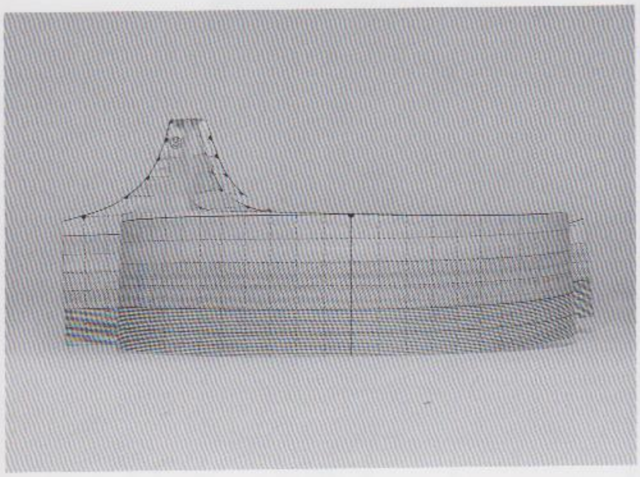


Image 2



potential. Electric potential is measured in volts, indicated by a large $V$. An electric potential of a certain point where there is static electricity is calculated as the following:

$$V \quad ko\,\frac{Q}{r}$$

$Q$ = size of static electricity at a point

ko is a constant first derived by the French physicist Coulomb. If you replace the size of the static electricity with $Q = 1.0 \times 10^{-9}$, the equation becomes much simpler:

$$V \quad \frac{9}{r}$$

Let's apply this calculation to building the model in the images;

If $r$ = 1cm, 2cm, 3cm, 4cm, 5cm, or 6cm, then $V$ = 9cm, 4.5cm, 3cm, 2.25cm, 1.8cm, or 1.5cm, respectively.

The "Mount Fuji" came from this inversely proportional equation. By taking complicated numbers and equations and making them into 3-D shapes, you can understand the real-life implications of physics.

Uh-oh, am I boring you? I'll bet I am.

All right, let's go ahead and skip to the more interesting part of my story.

Image 3

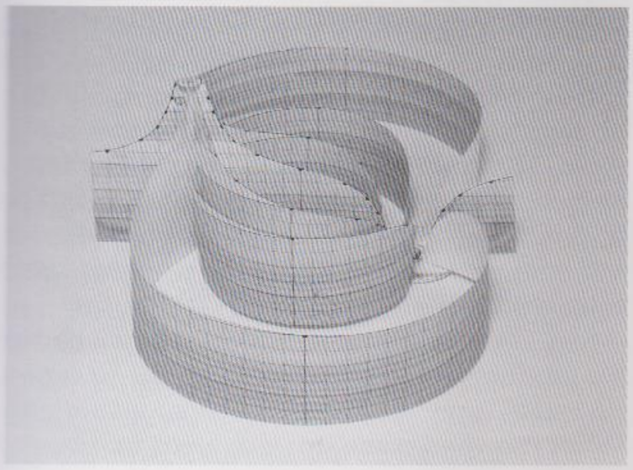
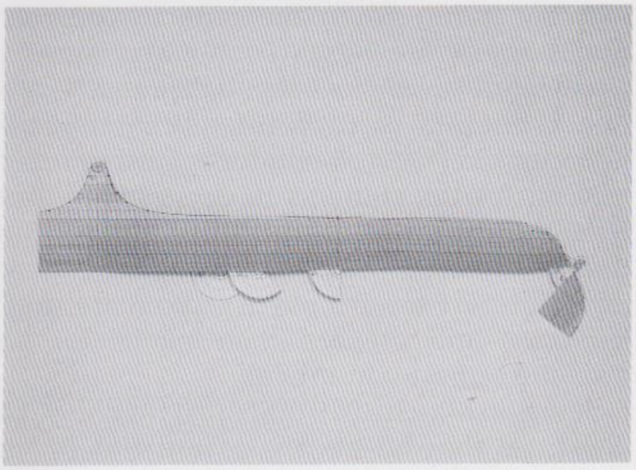


Image 4



"Let's do this one!" "No, that looks hard!" "How about this one?" My students were excitedly discussing the karakuri models.

Let me tell you a little bit about myself. I am a high school physics teacher. Paper craft is an important teaching tool for me. I develop paper crafts of my own and use them to teach the students in my classes. As I place the paper models in front of me and study them from various angles, I begin to see that various laws of physics that at first seem to have totally different qualities—such as size, shape, color, and texture—actually exist in unison. The world of art and the world of physics: I feel that there's always a connection.

In the professional study of physics, we use very complicated equations in order to express or calculate various natural phenomena. In high school physics, however, there are visual aids such as charts and graphs that help students use their imagination and understand better. I think this is one of the greatest things about high school physics.

Every spring when the new school year starts, I begin teaching students who have no knowledge of physics—they're "green," so to speak. But then we soon enter a long summer vacation. So I was looking for a good summer project for the students to do at home that would keep what they learned during the spring semester fresh in their minds, gear their interest toward physics, stimulate their curiosity, and prepare their minds for an exciting semester in the fall.

It was in March 2006 that I first met Keisuke Saka. He showed me the manuscript of his book *Karakuri*. Stick a finger inside a little hole and turn the handle clockwise, and a weird-shaped square axle rotates and moves a crank. That was all there is to it. The paper is smooth and easy to turn, and the square axle directly transmitted the force from the finger. I felt more possibility in this.

How will these models connect? What would my students make of these? I had never used a paper craft that moves in my classes. I became quite excited, and Saka and I agreed to use these kits as my students' summer projects.

So the long-awaited karakuri kits arrived in early July. Of the ten types of karakuri, each student chose just one. I displayed all the models and instructions to take a survey of which ones they wanted to make. The most popular were the gear and cam models, because they seemed pretty simple to make. The second preference varied, so I was able to give each student the kit that he or she preferred.

What would my students come up with? Would it feel more like an art project? I tried making one. I thought I had great ideas, but the models were so beautiful I didn't feel like adding much more to them. And the crank, gear, and cam mechanisms were extremely realistic. I thought, "This might turn out to be a tough project to do over a vacation!" I spent my summer praying that my students were taking on this project well.

September 1 was the first day of class. I had all my students bring their karakuri kits to report on what they had made. I was astounded. What they had come up with went far beyond

More than 100 karakuri paper toys were displayed on the first day of class. It was like a toy museum!

my expectations. High schoolers rock! Each student had documented their process and what they had done to make the models better. One student said, "With my Geneva stop, I had a hard time just trying to make it move." When I heard that, I said, "You're a high schooler, and you're talking professional physics! Just that fact makes your project worthwhile." Once they learned to make the basic models, they said it became much easier to develop them into real karakuri.

At the first physics class of the fall semester, I had everyone's masterpiece displayed on a row of desks in the back of the classroom. Then each student went to their work and turned the karakuri as I slowly slid from one end of the row to the other, recording them with a video camera. The students were to look into the camera, say the title of the work, and turn their piece as two TV monitors showed the recorded footage.

"Uh, what was the title of my thing? I guess I'll just call it 'Untitled.'"

"Which way am I supposed to turn this?"

"Where is the camera?"

"Oh, no, my handle doesn't budge!"

The students all seemed a bit nervous in front of the camera, but a lineup of such a variety of creative karakuri was quite impressive. Students raised their voices in surprise when someone's karakuri made unexpected movements. When we were all done, everyone was smiling. The karakuri show-and-tell turned out to be a lot of fun.

After the show-and-tell session, I displayed the students' works in the physics room for other people to see. Placed all in one row, it was like a paper-craft toy museum! When students from other classes or schools came and saw the works, everyone was quite interested, and, although no one was allowed to touch the works, I think people would have enjoyed trying out the karakuri for themselves and seeing how the parts actually move.

Robots, arguably the pinnacle of scientific technology today, are made of a combination of various karakuri–like mechanisms. There isn't a course on mechanical engineering in high school physics, but karakuri paper craft is a perfect tool to teach students about the lever mechanism, force momentum, and force transmission or conversion. Paper craft is also ideal because it has room for creativity, allowing the students to make their own designs.

And so *Karakuri* has become one of my favorite teaching tools. I hope to further widen the horizon of using paper crafts to get the students excited about learning high school physics.

**Masayuki Kobayashi**
High School Teacher of Physics
Tama University Hijirigaoka High School, Tokyo, Japan

## Author's Biography

### Keisuke Saka

Paper engineer/graphic designer
www.zuko.to/kobo/

Born in 1965, Saka graduated from Kobe University, Kobe, Japan, with a degree in literature. After studying visual design at Kuwasawa Design School, in 1994 Saka became a freelance graphic designer and started creating paper-crafts. While living in Denmark from 1997-2000, he was fascinated by European automata, or mechanized puppets. Upon returning to Japan in 2000 he established Zukoshitu, his own paper-engineering/design office. His works include paper-craft kits, advertisements, Web design, magazine contents, and books. He has held paper-craft workshops in various cities in Japan, and in 2008, a series of his workshops were broadcasted on NHK (Japan Broadcasting Corporation), the national TV education program. His "Karakuri Paper-Craft" series is also sold in the U.S. and Europe, available through Noted, Co. (http://www.notedco.com)

## Contributors' Biographies

### Masayuki Kobayashi

High School Teacher of Physics
Tama University Hijirigaoka High School

(2008–, Teacher of Physics, Tokyo Gakugei University Senior High School)

Born in 1962, Kobayashi graduated from Tokyo Gakugei University with a degree in education. While teaching at Tokyo Metropolitan Katakura High School he involved himself in developing courses in sculpture, after which he began integrating artistic concepts into physics education. He has taught at Tokyo Metropolitan Aoyama High School, in NHK's high school seminar of physics, and at Tama University Hijirigaoka High School. Currently teaching at Tokyo Gakugei University Senior High School, Kobayashi is active in developing physics education using everyday objects and writes high school textbooks and other books on science.

### Yasuyuki Shirai

President, Japan Mechanism Art/
Professor, Chiba Institute of Technology

Born in 1941, Shirai graduated from Chiba Institute of Technology with a degree in electrical engineering. After working at Tokyo Institute of Technology Teacher Training Center and advanced mechanical and electrical engineering programs at Chiba Institute of Technology, he is currently head of educational department at Chiba Institute of Technology. Shirai is the founder of Japan Mechanism Art, a study organization of mechanical creativity holding karakuri exhibitions and performances throughout Japan.

### Toshio Arai

CEO, Concept Plus Co., Ltd.
www.conceptplus.jp

Born in 1952, Arai graduated from Sophia University with a degree in mechanical engineering in 1976 and began working for Sony Corporation as a technical engineer. He is an important figure in the development of Walkmans, CD Walkmans, and stereos. In 2003, after 27 years at Sony, he established Concept Plus Co., Ltd. His company initiated "Kyouiku Shokunin Project" in 2007 and creates products for people of all ages, with concepts such as "For the children to have a dream in science," and "Protecting our precious Earth."

## Translator/Designer's Biography

### Eri Hamaji

Translator/graphic designer

Born in 1982, Hamaji graduated from the Cooper Union School of Art, New York, in 2005. After working at Mori Art Museum in Roppongi, Tokyo, she currently translates, coordinates, and designs creative books. She has written and translated for THEME magazine, New York, and translates and designs books for Mark Batty Publisher, LLC., New York, including *Everyman's McLuhan*, *Everyman's Joyce*, *FACE FOOD*, and *Graffiti Japan*.

## INDEX

## Afterword

In the process of working on paper-craft designs, I give birth to many test models made with simple white paper (in the world of painters they call it a "rough sketch"). I make a lot of test models, especially for karakuri paper-crafts, because a difference of even a few millimeters could affect how the parts move. By the time I finish designing one karakuri, there are countless test models scattered around my desk. I no longer need them because I have the final design done, but they *are* my creations, and I feel bad throwing them away. At one point, I began keeping some of them to display on my shelf. White is the color of a blank canvas, stimulating one's creativity. Just staring at these test models sometimes brings me the best ideas.

One day, when I was turning a handle of one of those test models, waiting for a good idea to come to me, I said to myself, "What if this *is* the final model for a kit? Why not!" Back then, I was making paper-craft kits to sell individually, and I was starting to realize that most tools and machines around us are all made from just a few simple mechanisms, only combined or different in size. I thought, "What if I write a few pages of text to explain those simple mechanisms and make a whole book for beginners?" And that is how this book started.

But of course, it's always easier said than done. I wasn't the best student of physics, and for the first time in my life I dug into a book on mechanical engineering, trying to figure out how to read through these pages full of unfamiliar equations and symbols. If it weren't for Mr. Arai, who patiently stayed with me and my project from beginning to end, Mr. Shirai, who kindly gave me technical advice, and Mr. Kobayashi, who shared with me his great knowledge on how to teach things to other people, it would have been impossible for me to write this book. I also want to thank Mr. Koseki, president (and paper-craft officer) of Shubunsha, the Japanese publisher of the original book, who had to endure my slow progress for a few years after giving me the okay to publish this book, without complaining a bit.

I also want to thank each and every Tama University Hijirigaoka High School student who participated in this project. It gave me the biggest thrill to see everyone's masterpieces displayed in the physics classroom. I will never forget that feeling. I'd like to thank you all very much.

Last but not least, I would like to express my deep gratitude to Ms. BJ Berti who edited this book, Ms. Jasmine Faustino, and everyone at St. Martin's Press. Thank you very much for all your help in publishing this English edition of *Karakuri*. I would also like to thank Ms. Eri Hamaji, who worked on both the translation and the design of this book.

One of the most wonderful things about paper crafts is that you can experience the joy of making something of your own that you can play with and have fun. I was very conscious of leaving a lot of room for your own ideas and creativity in these karakuri paper crafts. My wish is that this book will open a door to your journey to discover the pleasure in making things your own.

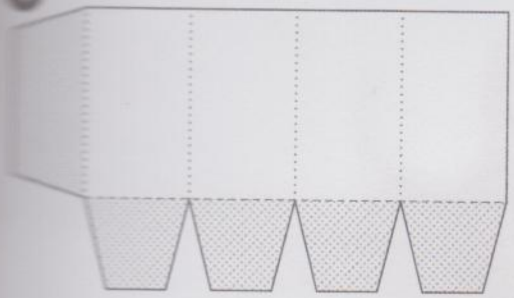
Keisuke Saka

# 4

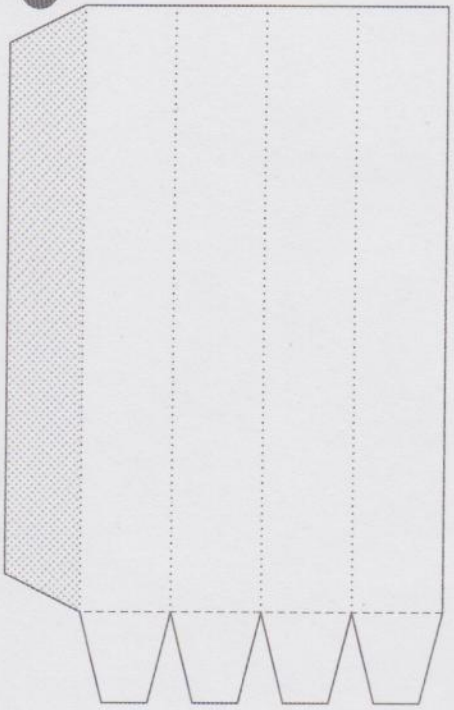
## Basic Karakuri Models

! These pages are meant to be torn out of the book and cut to be used as building materials for the model.

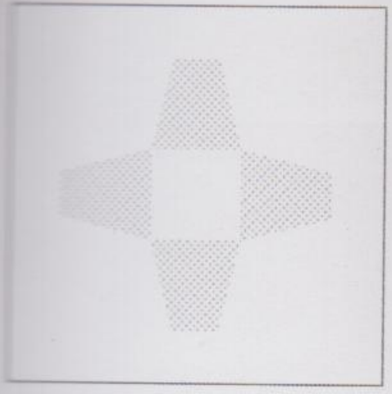
1



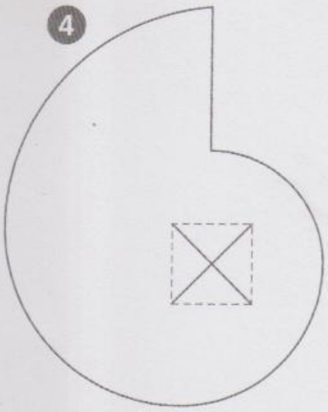
2



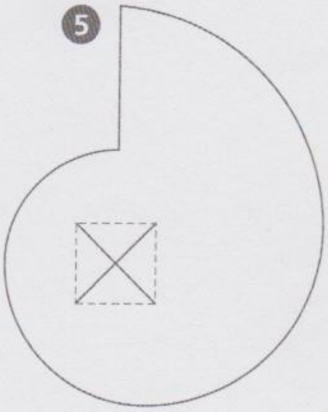
3



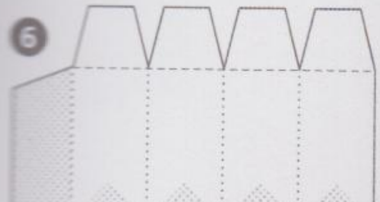
4



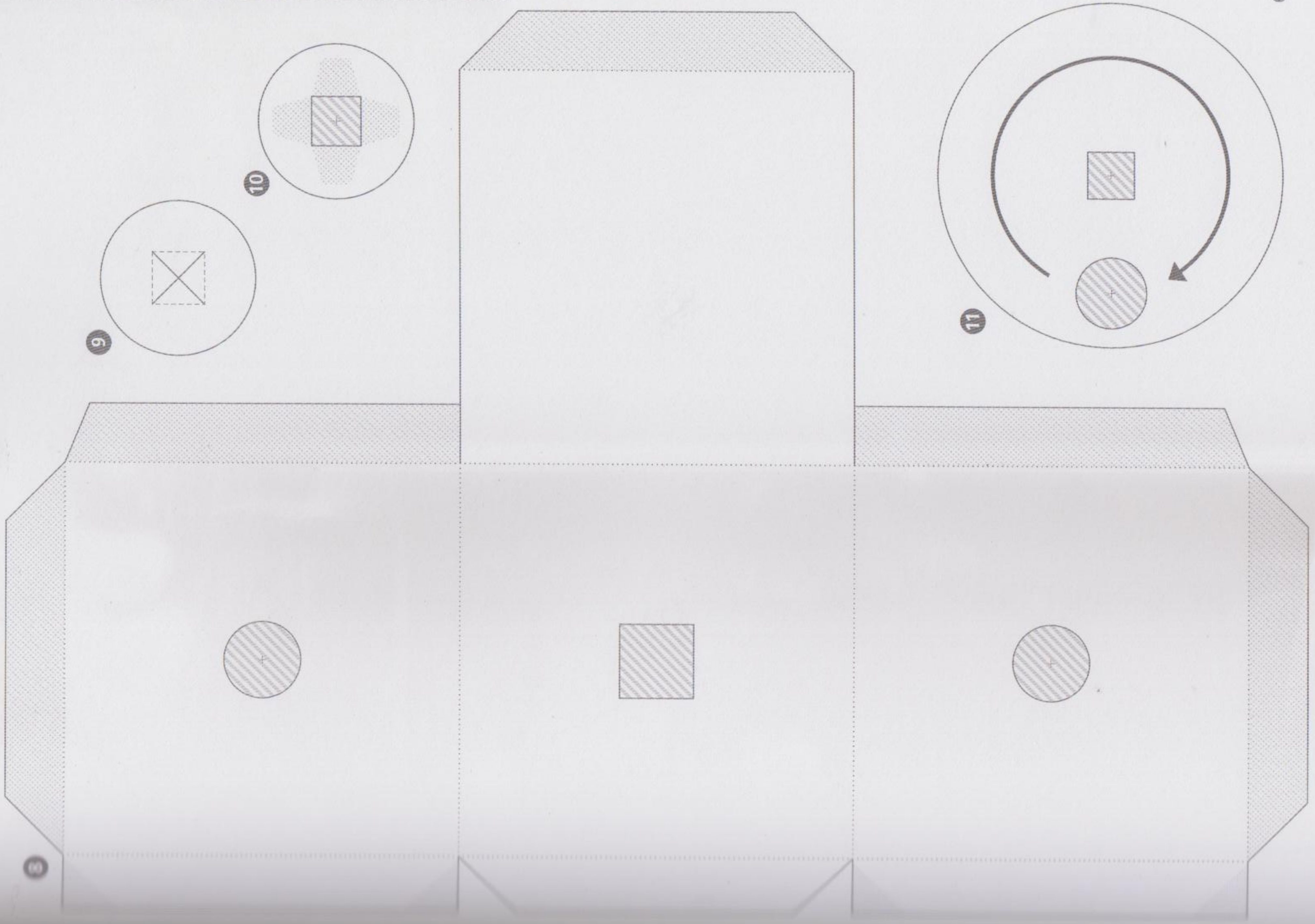
5

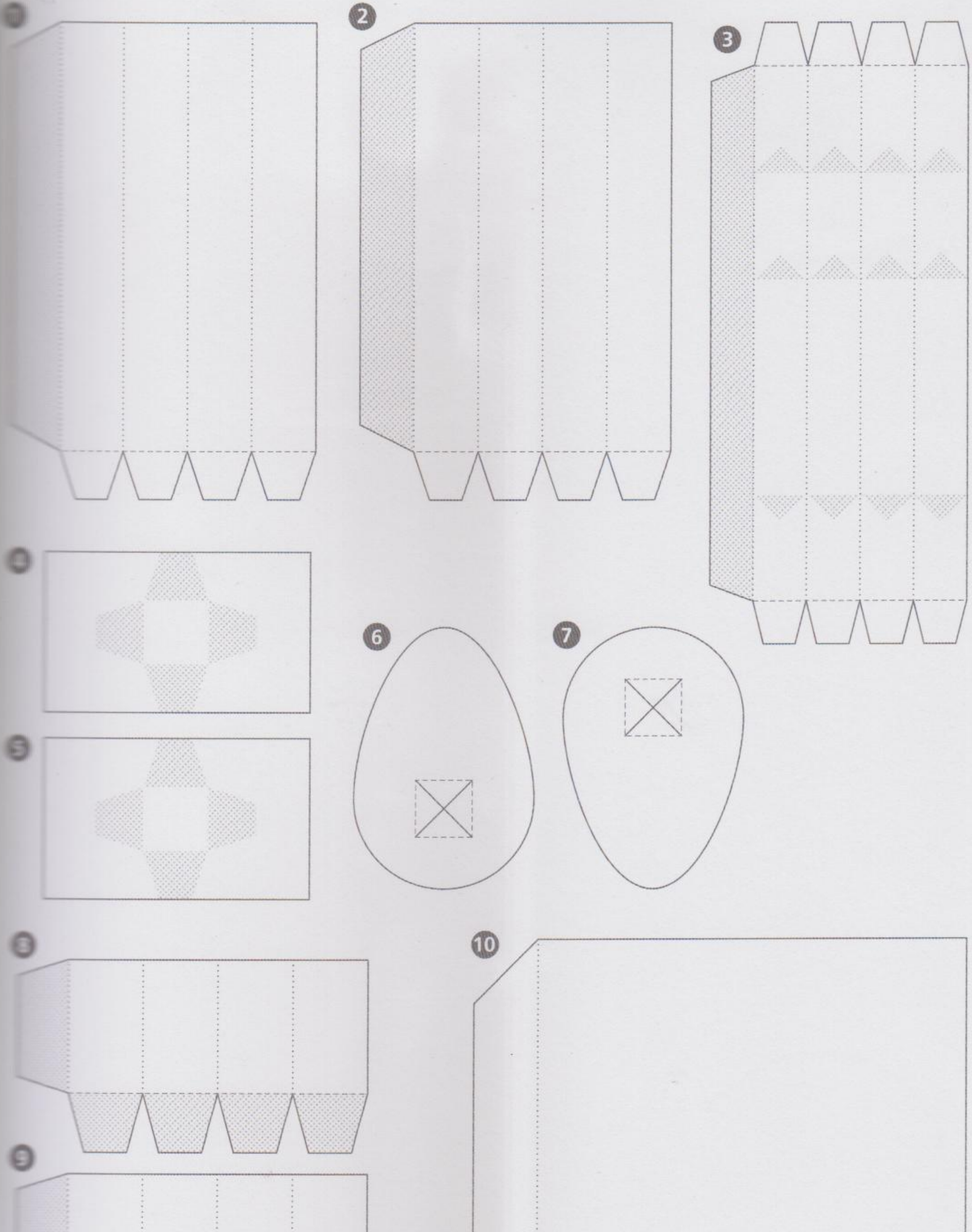


6

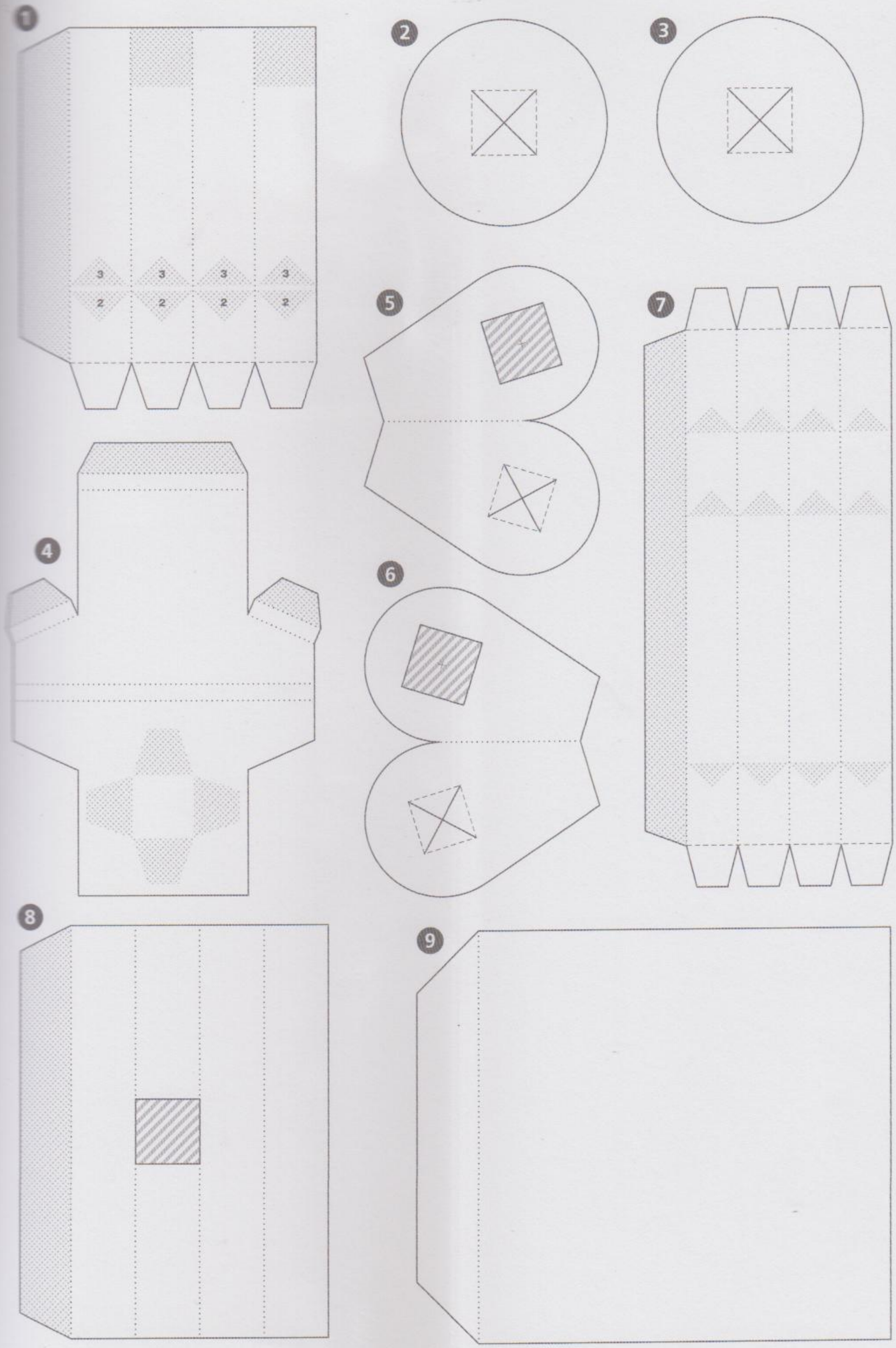


7

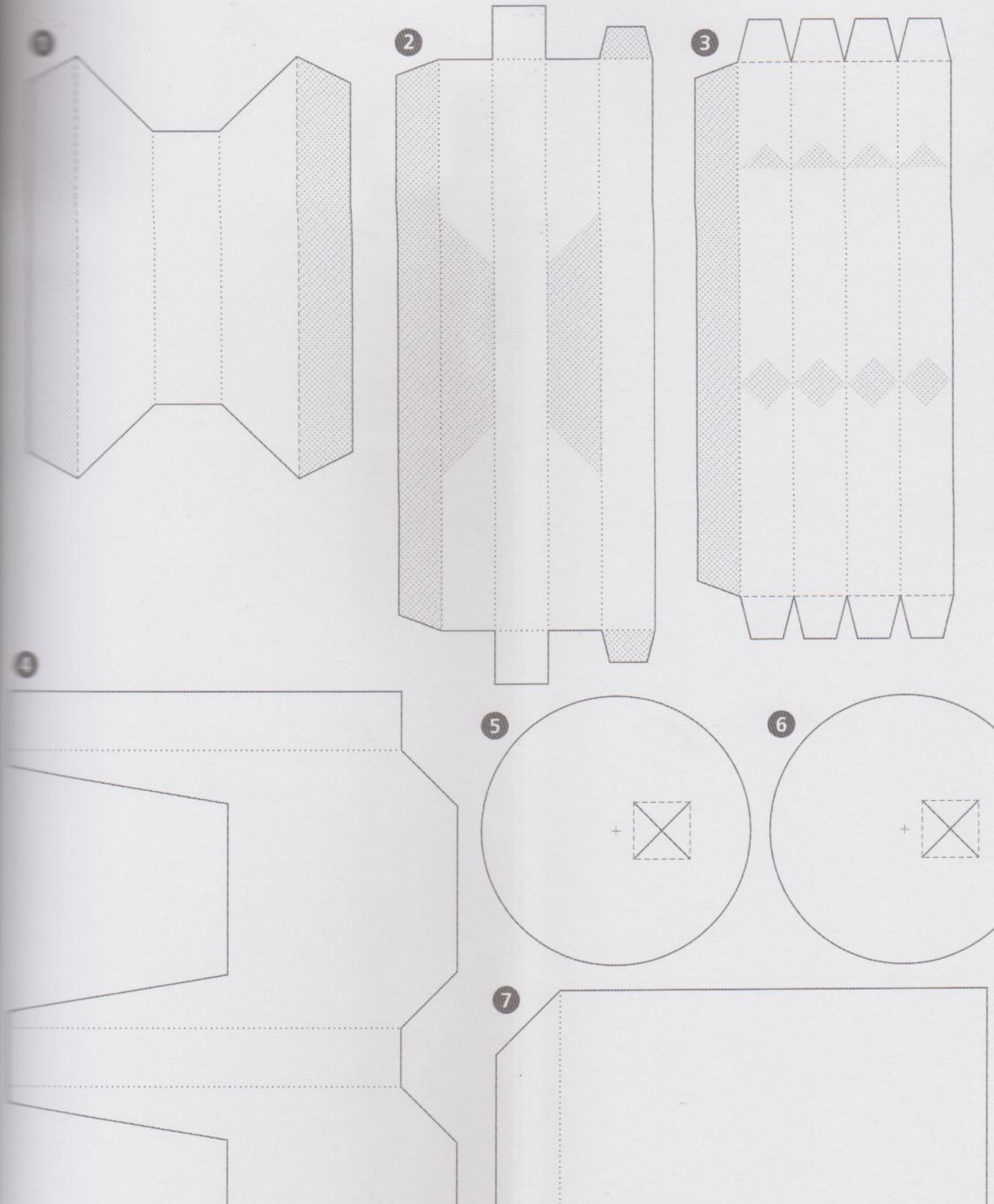

8
9
10
11



12
13
14
11

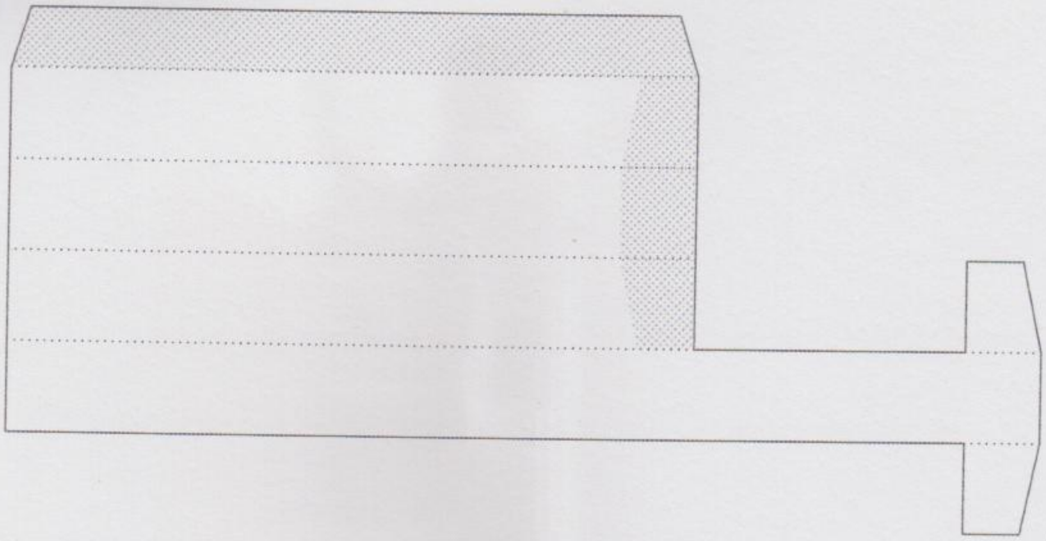

1
2
3
3 3 3 3
2 2 2 2
4
5
6
7
8
9


11
12
13
10

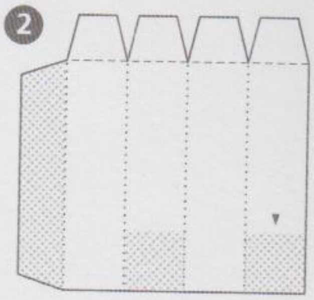

1
2
3
4
5
6
7

8
9
10
11

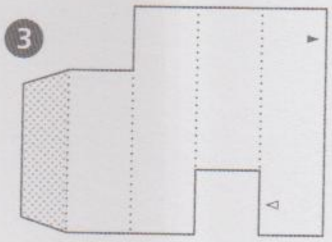
1



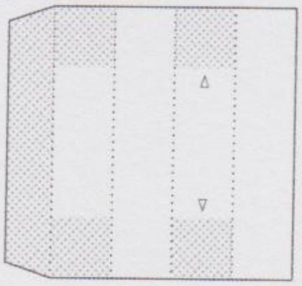
2



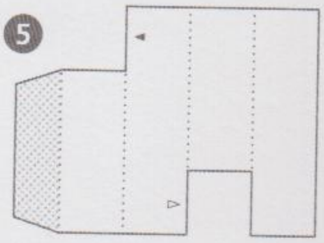
3



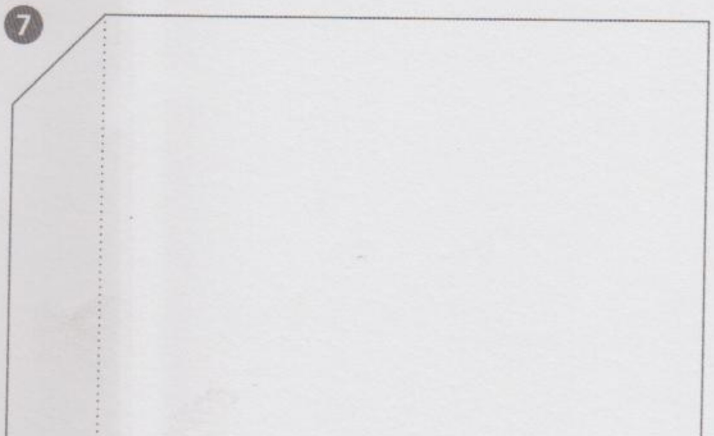
4



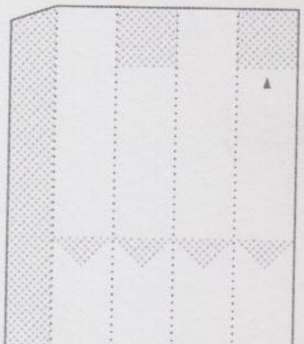
5

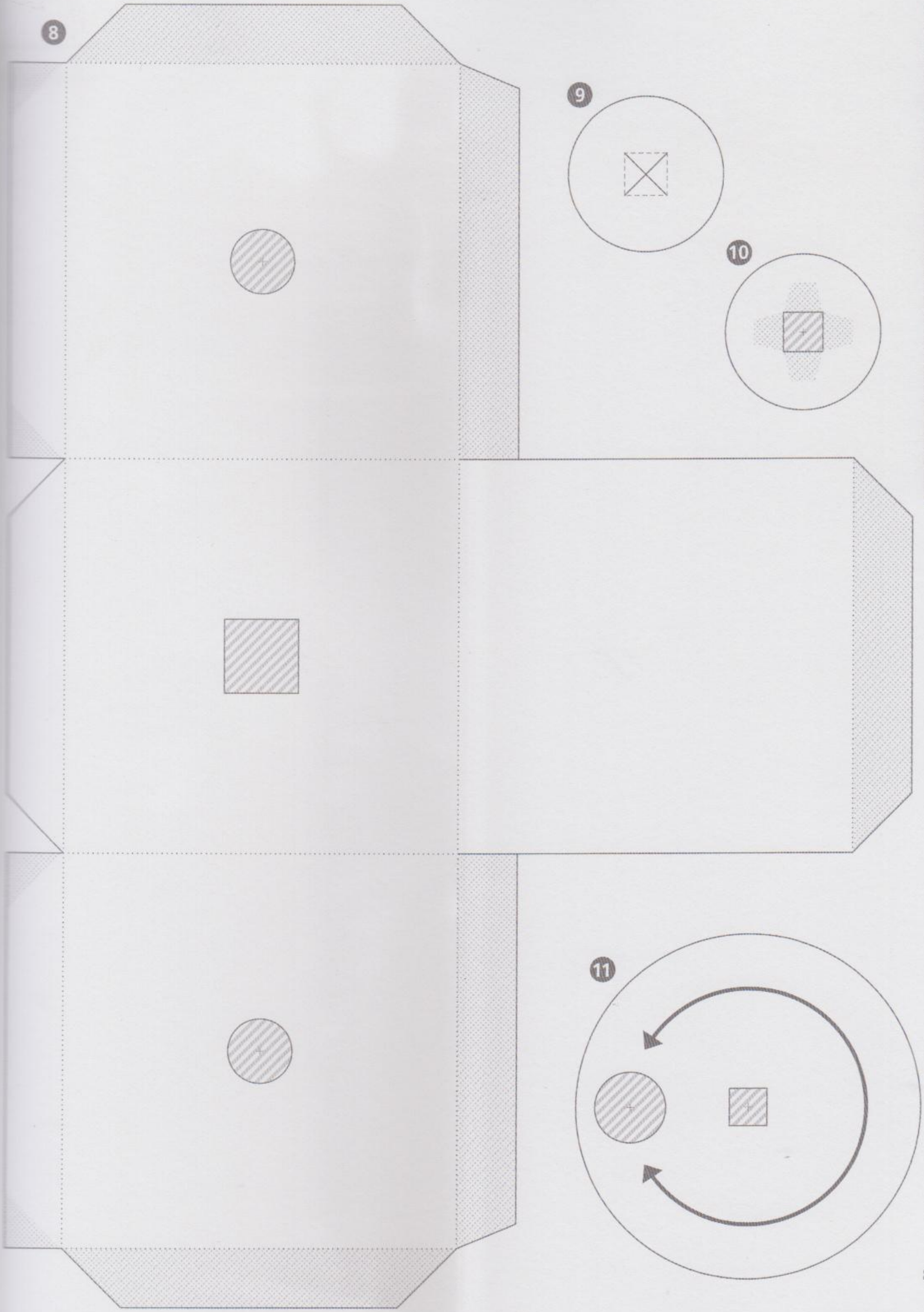


7



6

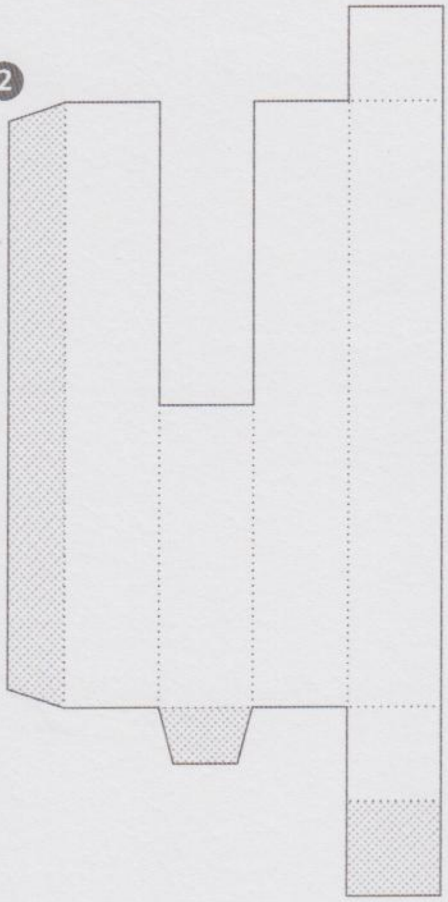




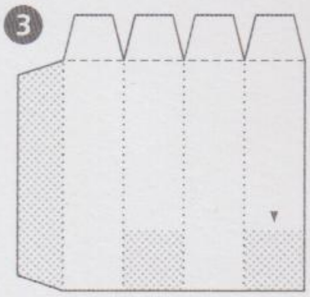

8
9
10
11

1

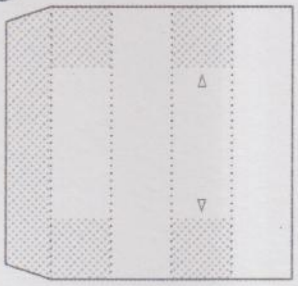
2



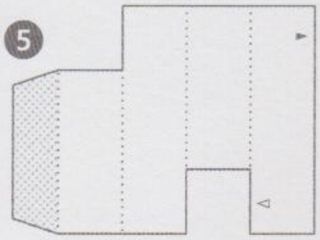
3



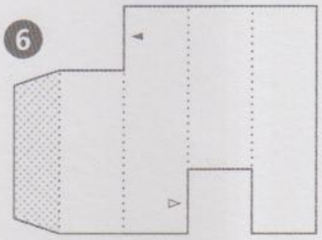
4



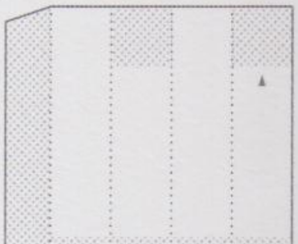
5



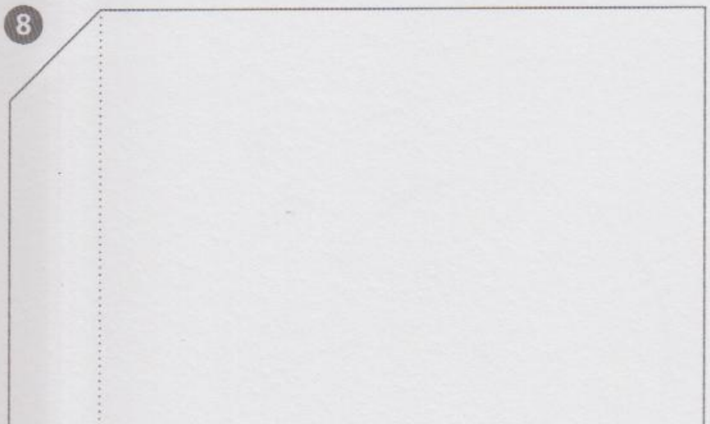
6

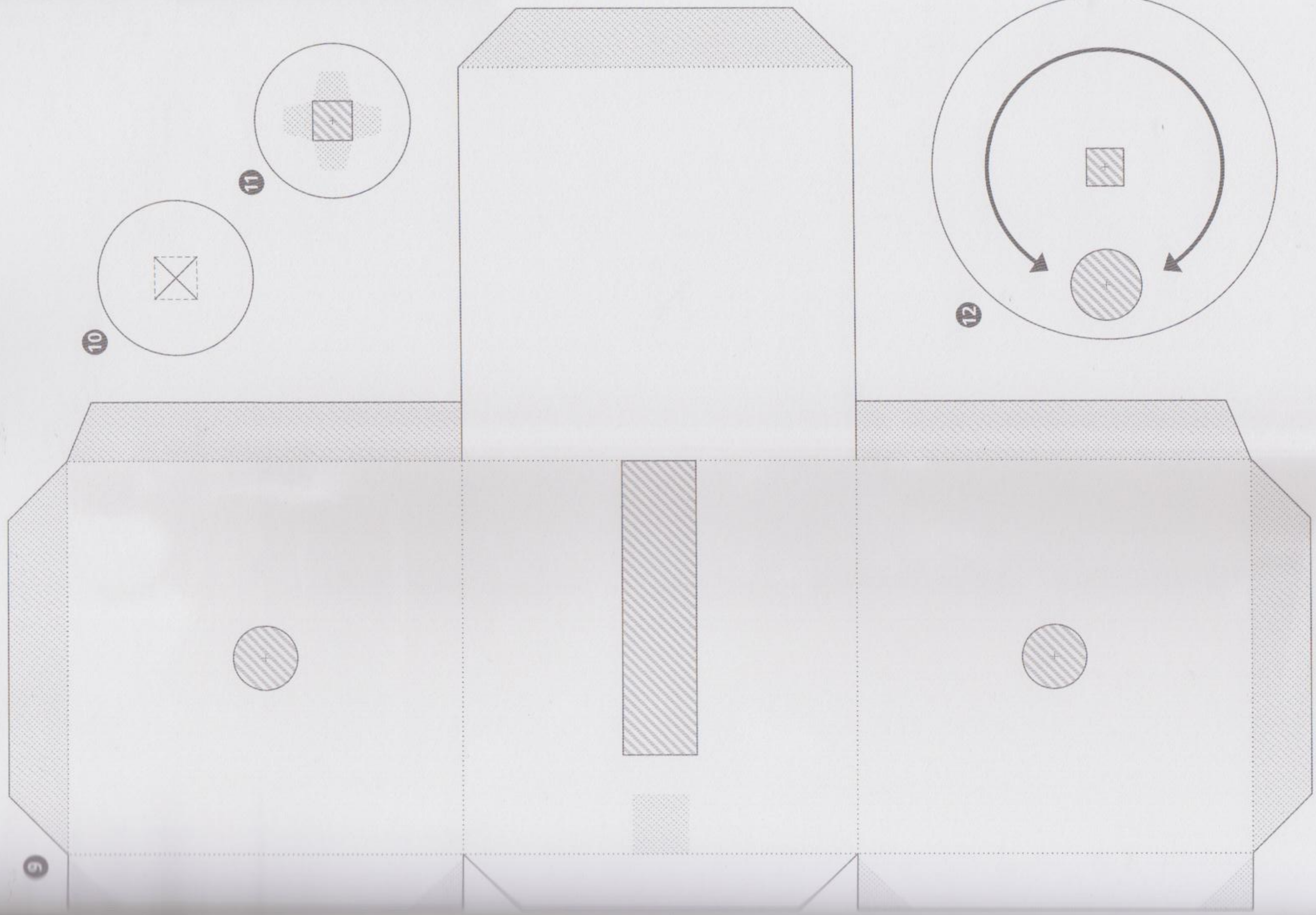


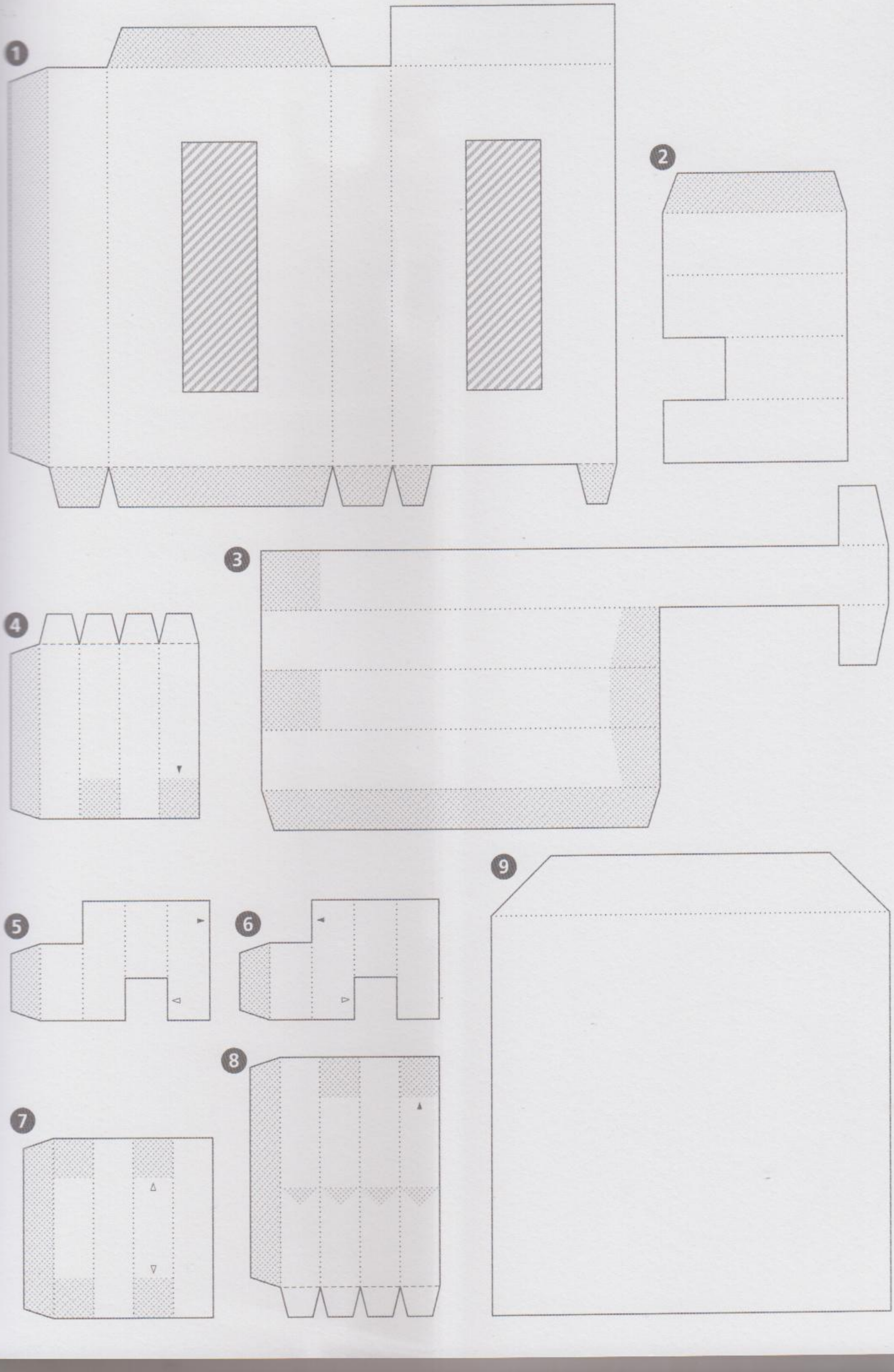
7

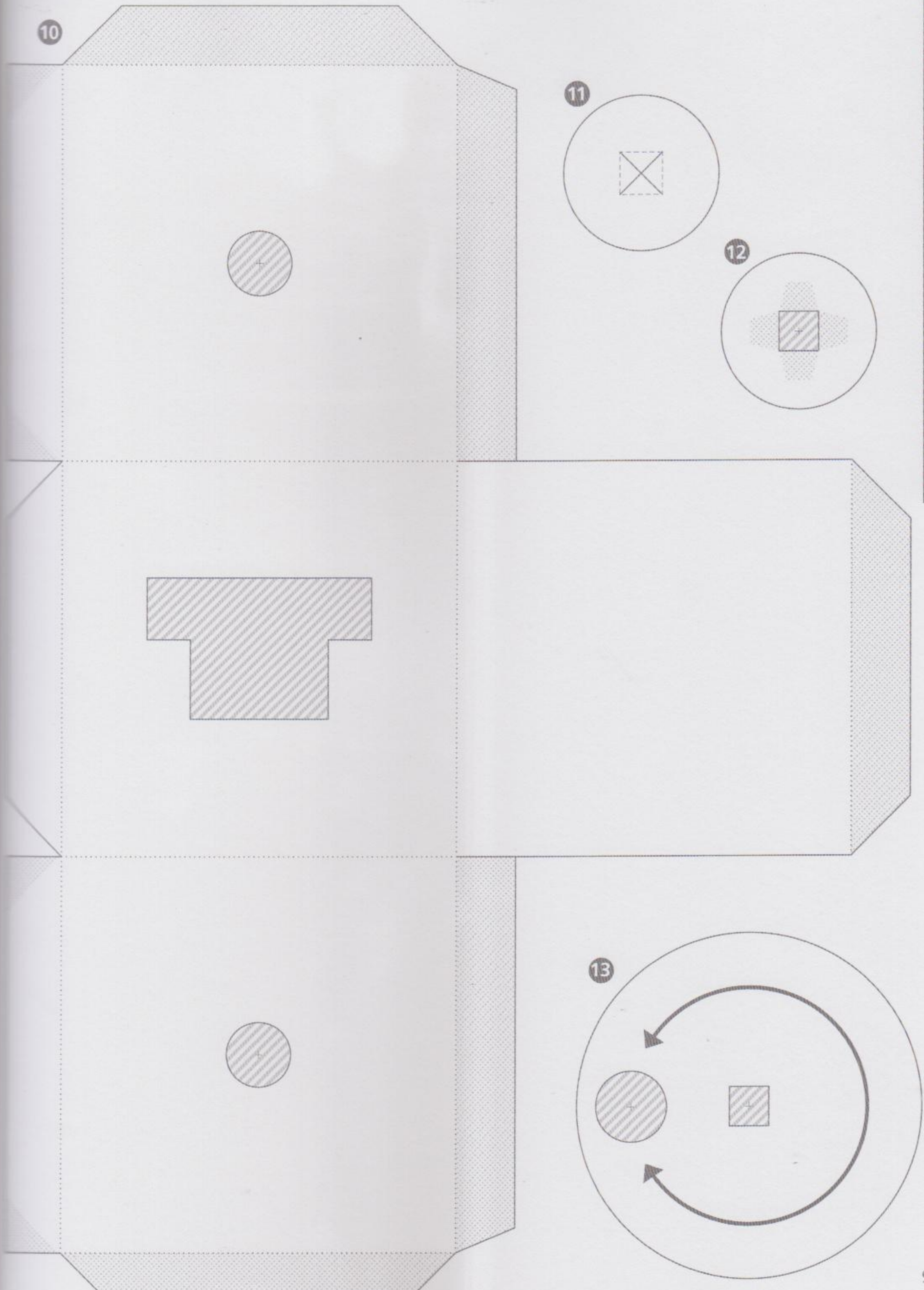


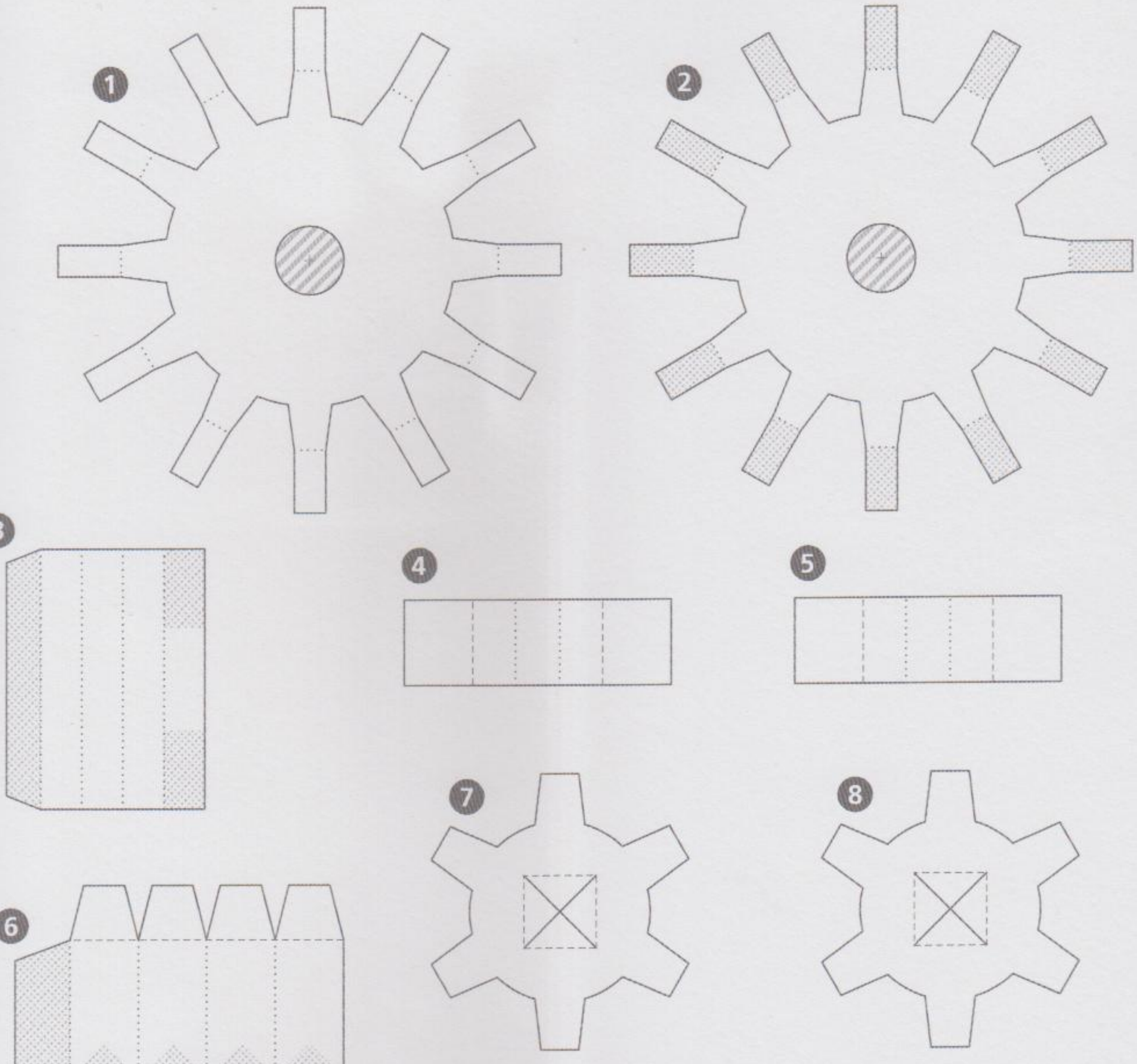
8

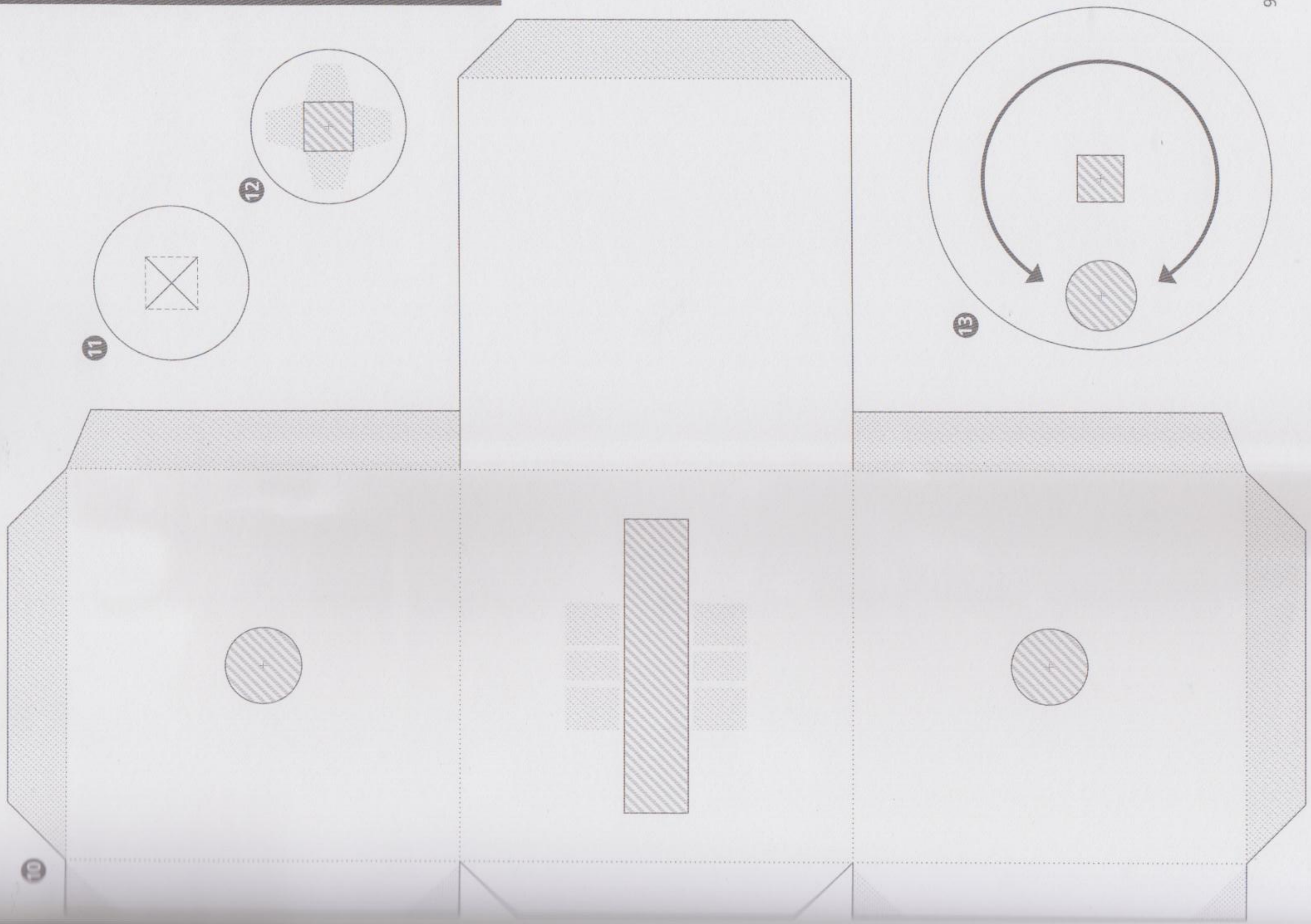


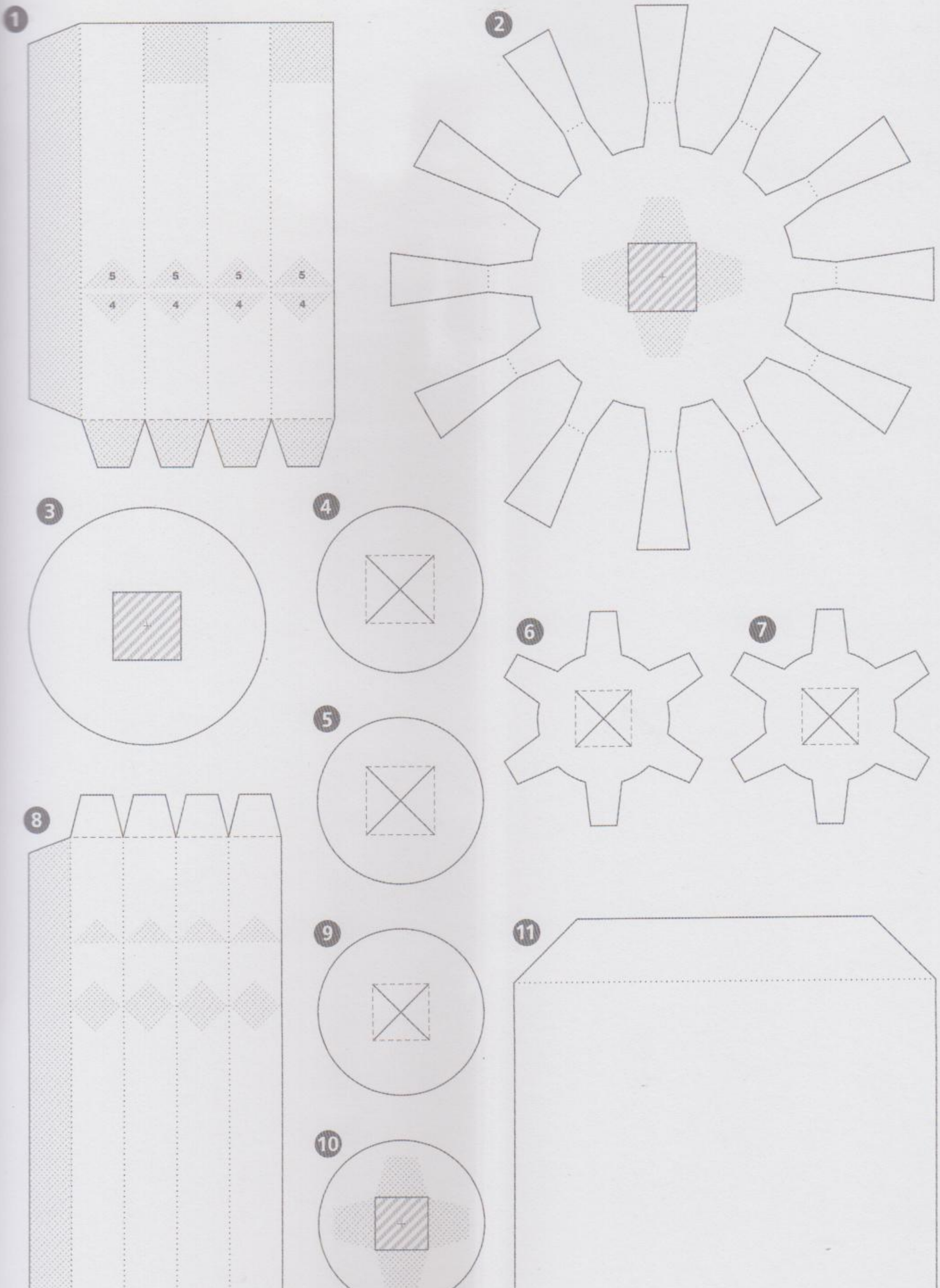

9
10
11
12


1
2
3
4
5
6
7
8
9


10
11
12
13


1
2
3
4
5
7
8
6
9

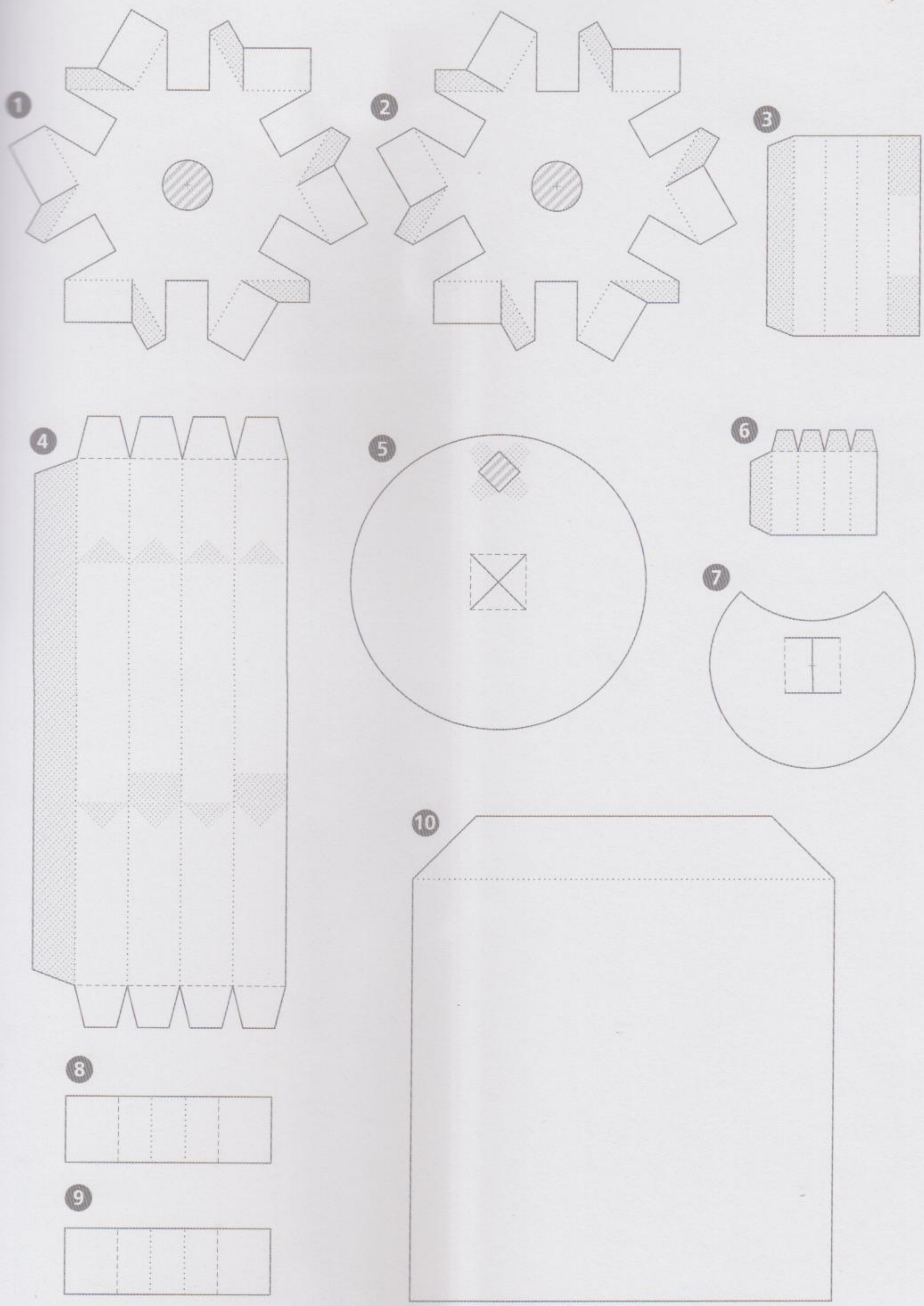

11
12
13
10

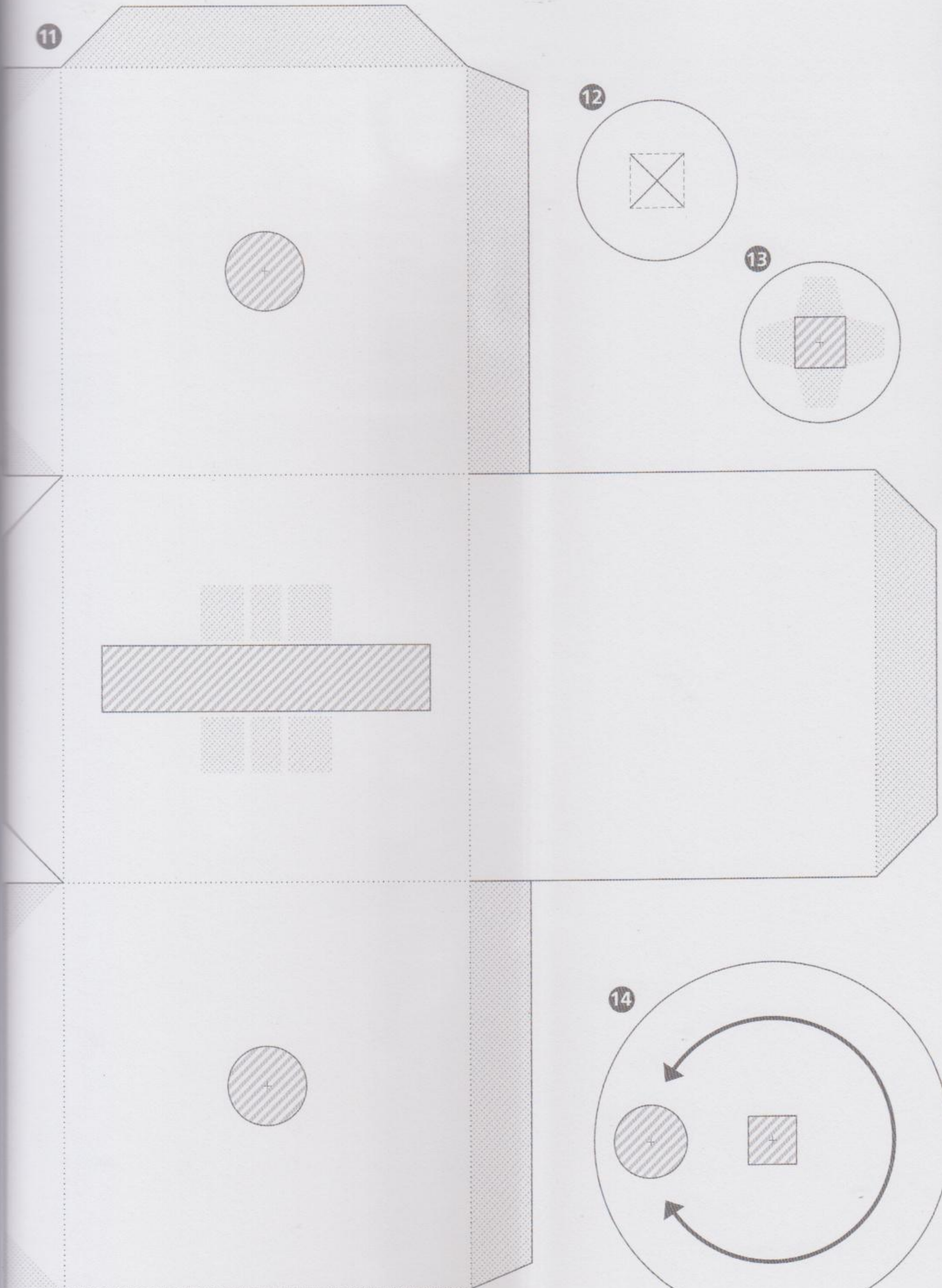

1
2
3
4
5
6
7
8
9
10
11

13

12

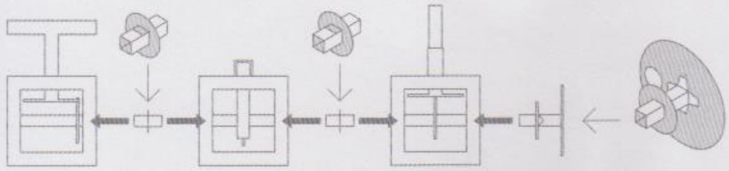
14


1
2
3
4
5
6
7
8
9
10


11
12
13
14

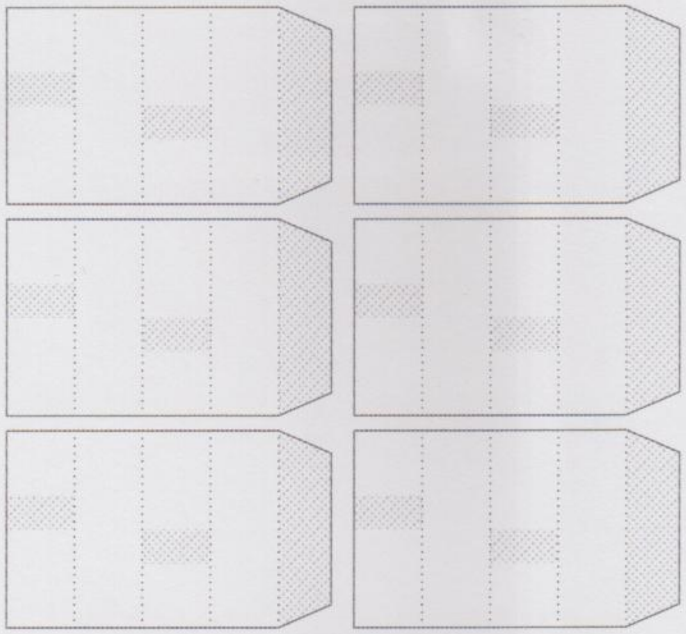
**Seven of the ten basic karakuri models (Cam A, Cam B, Cam C, Cam D, Gear A, Gear B, and Geneva stop) can be joined to make a model connected with one handle.**

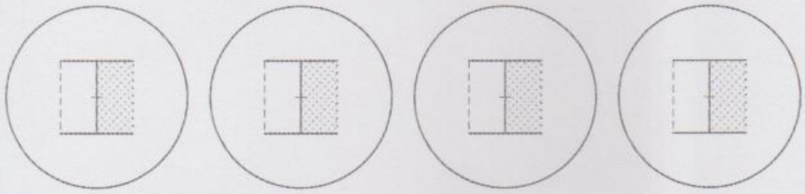
1. Make each karakuri model mostly according to its instructions, but replace some of the parts in the model's cutting materials page with the parts below, indicated by number. Do not attach the handle to the axles. You should end up with separate models with square holes on the sides.
2. Place the models next to each other in the order you want, and insert the joining parts to connect them. No gluing is needed.
3. Build the insertable handle and insert it into the model on the end. You can try connecting the models in different combinations.

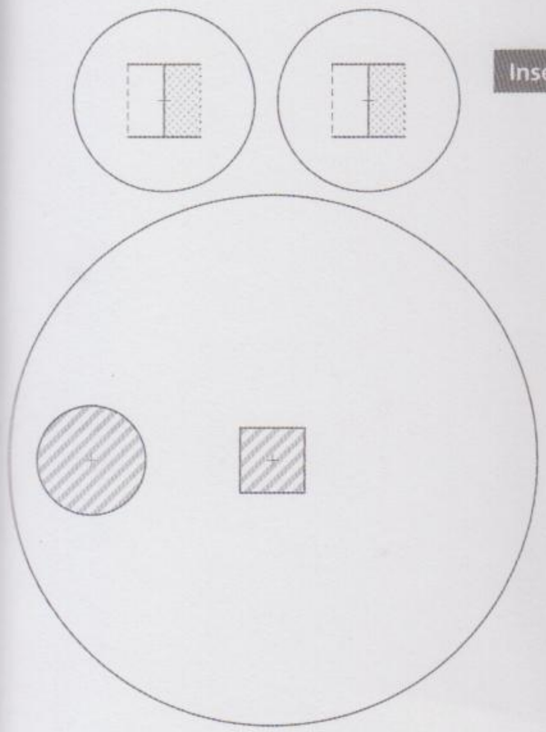


**For all 7 types**

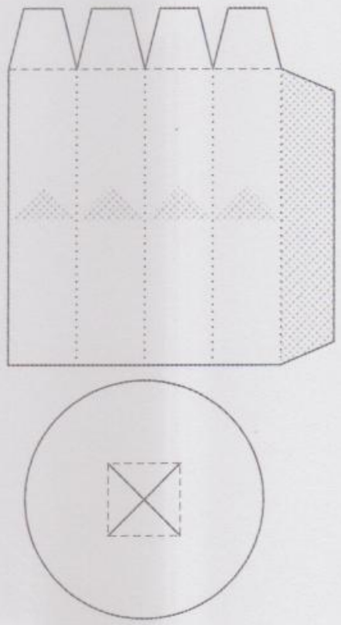
**Joining parts x6**







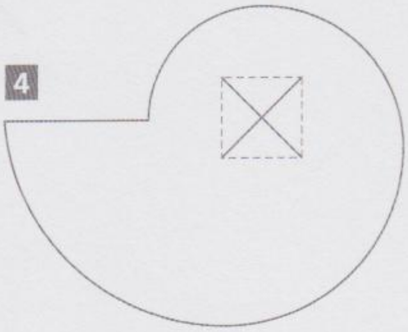
**Insertable handle**



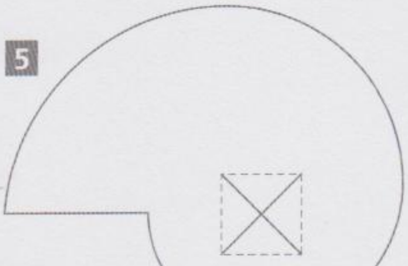
**Cam A**

6

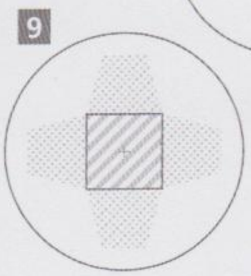
4



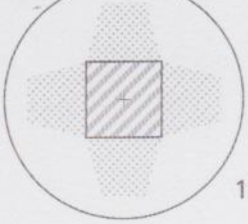
5



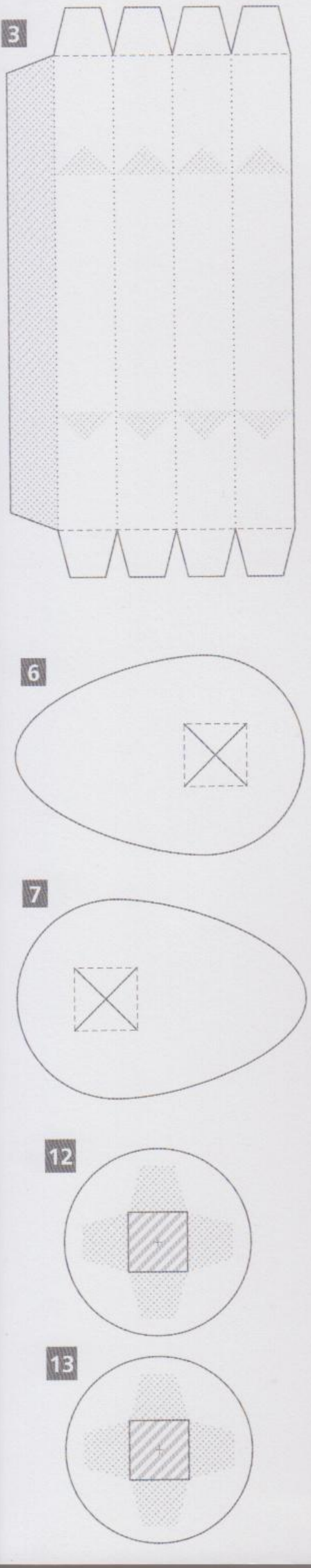
9



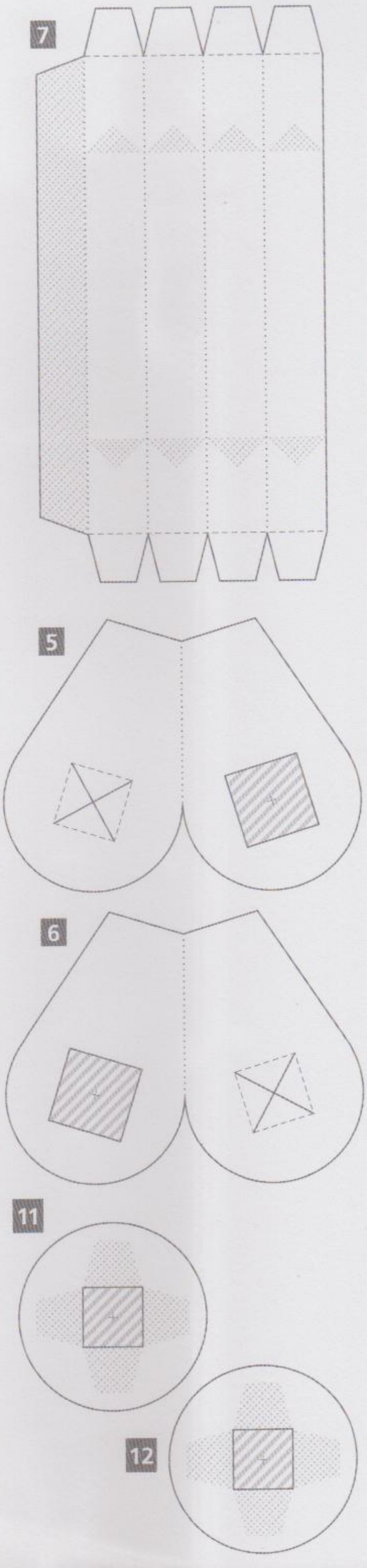
10



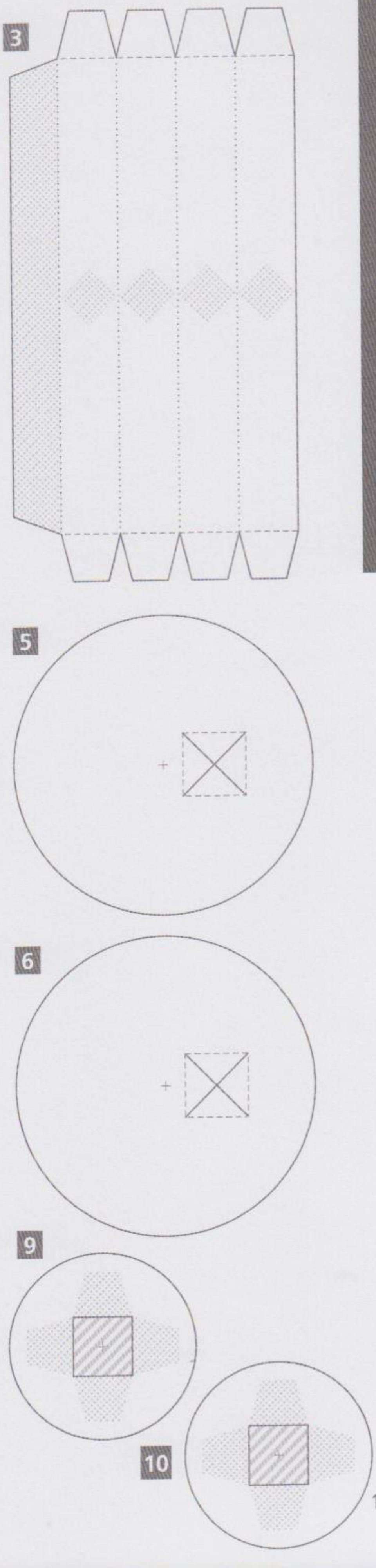
## Cam B



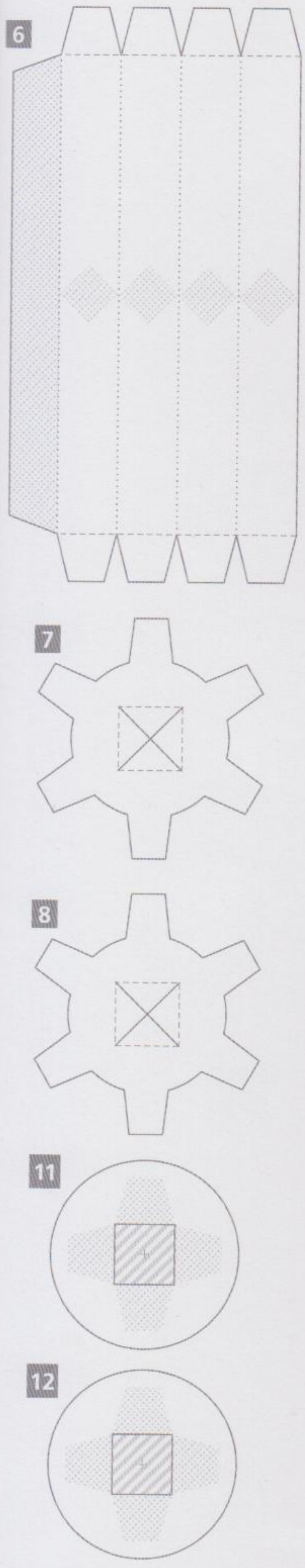

## Cam C



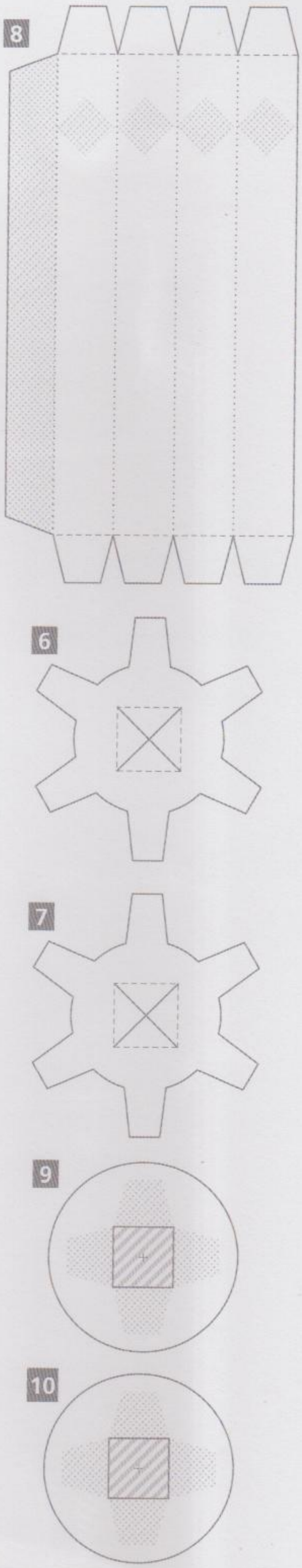

## Cam D



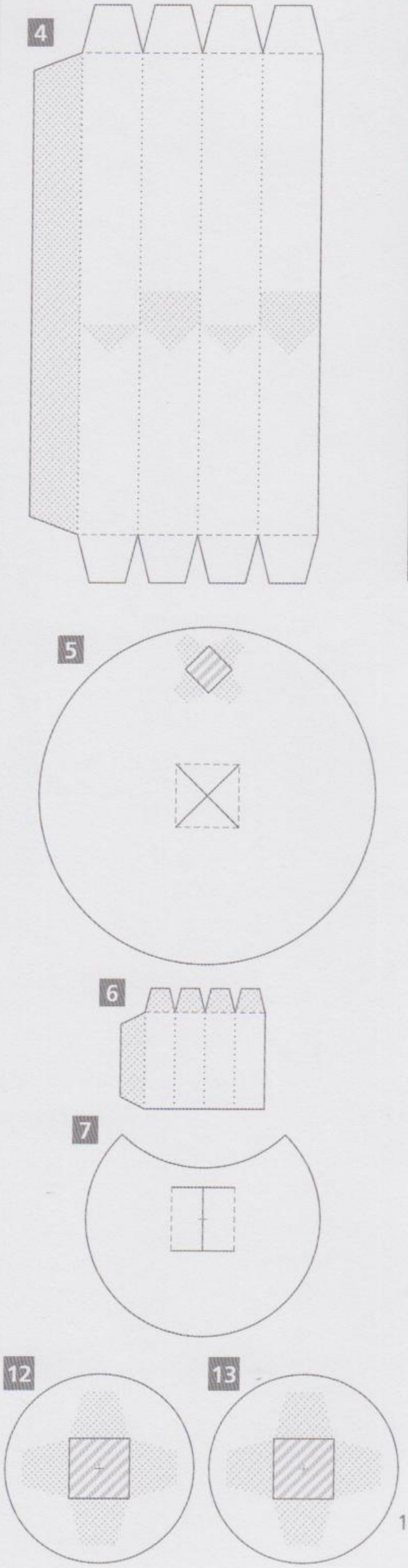
## Gear A




## Gear B

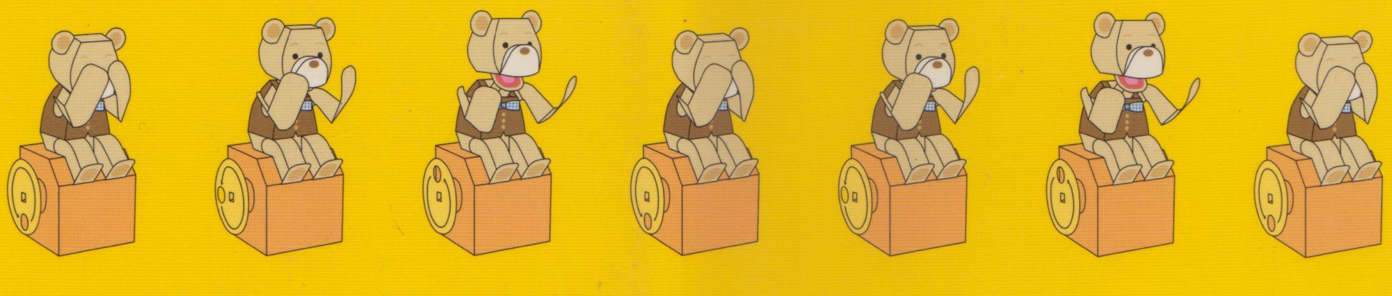



## Geneva Stop



Learn how to make your own moving automata with this book from well-known Japanese paper engineer Keisuke Saka.

*Karakuri* includes printed full-color, pull-out pages with all the parts for constructing four amazing models:



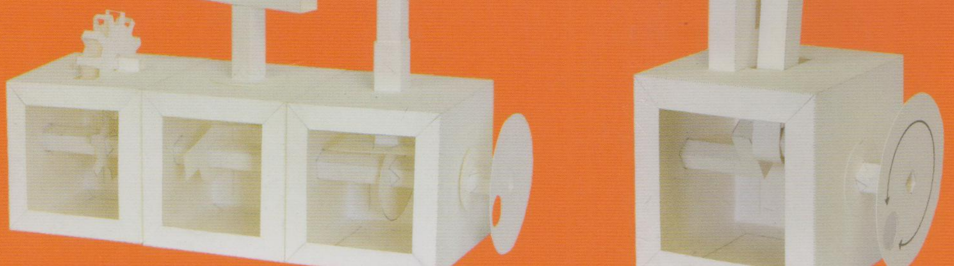
• A whimsical tea-serving robot

• An amusing penguin perched on an iceberg and trying to fly

• A delightful peek-a-boo-playing teddy bear

• A mesmerizing train that goes around on a track and through a tunnel

Plus additional pull-out pages you can use to construct the types of gears, cams, and other mechanisms to create your own moving models



ISBN 978-0-312-56669-2
52499 >
9 780312 566692